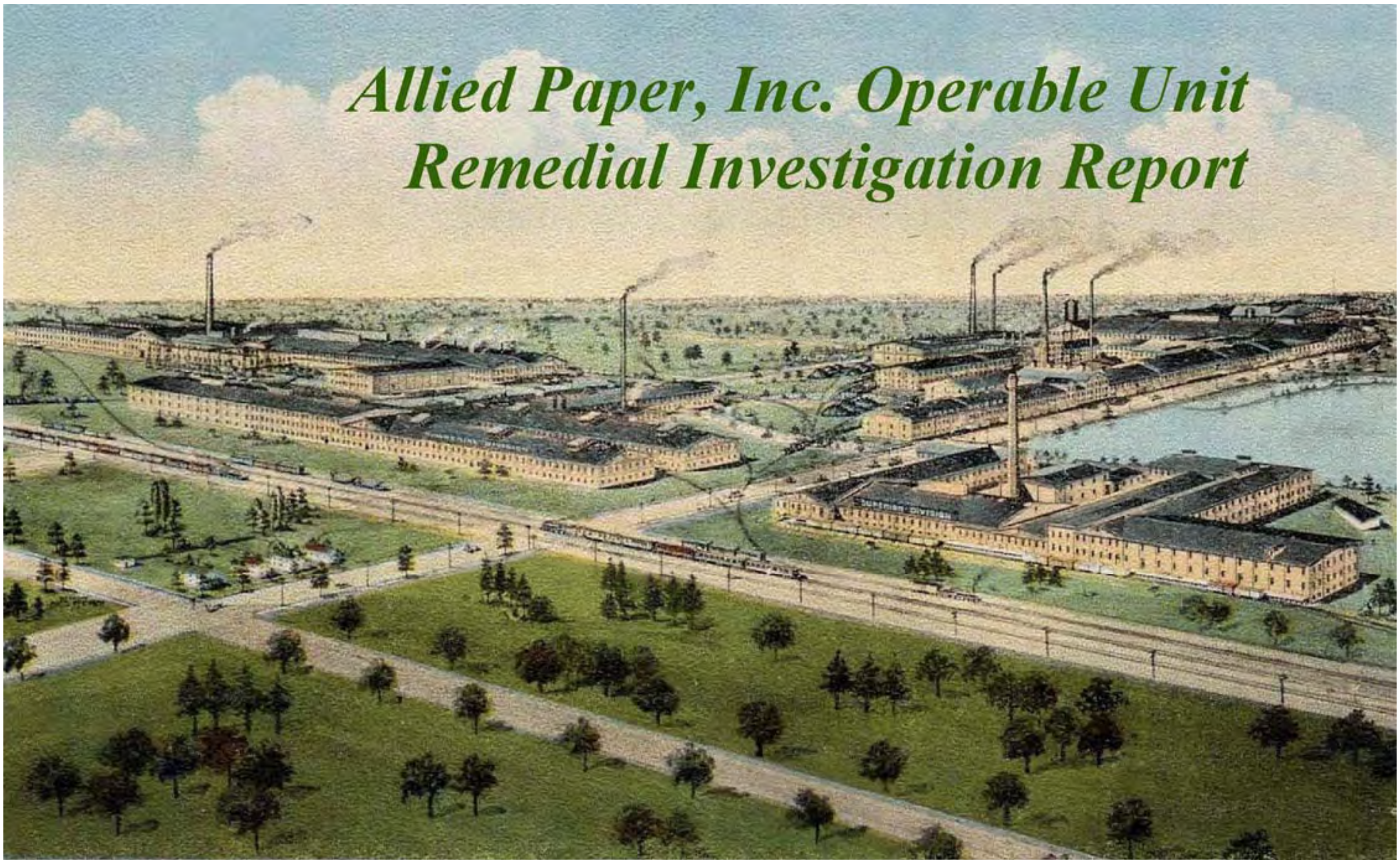
Allied Paper, Inc./Portage Creek/ Kalamazoo River Superfund Site



Allied Paper, Inc./Portage Creek/ Kalamazoo River Superfund Site Kalamazoo, Michigan

March 2008

Prepared For: MDEQ
Prepared By: CDM

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

JENNIFER M. GRANHOLM
GOVERNOR

STEVEN E. CHESTER
DIRECTOR

March 19, 2008

Mr. Michael Berkoff
United States Environmental Protection Agency
Region 5
77 West Jackson Boulevard (SRF-6J)
Chicago, Illinois 60604-3507

Dear Michael:

SUBJECT: United States Environmental Protection Agency (U.S. EPA) Comments on the State-Approved Remedial Investigation (RI) Report for the Allied Paper Operable Unit (OU1)

The Michigan Department of Environmental Quality (MDEQ) received comments regarding the State-Approved RI Report from the U.S. EPA on March 7, 2008. As requested, the MDEQ has incorporated changes to the RI that were detailed in the U.S. EPA correspondence. As such, the MDEQ considers this latest version of the RI report to be a U.S. EPA-Approved document.

Should you have any questions or comments regarding the Final RI document, please do not hesitate to contact me.

Sincerely,

Paul Bucholtz
Project Manager
Specialized Sampling Unit
Superfund Section
Remediation and Redevelopment Division
517-373-8174

Enclosure

cc: Mr. James Saric, U.S. EPA
Mr. Lawrence Schmitt, U.S. EPA
Ms. Eileen Furey, U.S. EPA
Ms. Polly Synk, Michigan Department of Attorney General
Mr. Andrew W. Hogarth, MDEQ
Ms. Patricia McKay, MDEQ
Ms. Daria W. Devantier, MDEQ
Ms. Nanette Leemon, MDEQ
Mr. James Heinzman, MDEQ
Ms. Judith Gapp, MDEQ
Mr. John Bradley, MDEQ

Table of Contents

Tables

Tables on Enclosed DVD

Figures

Appendices

MDEQ Appendices

USEPA Appendices

*Materials in these appendices are found only on the enclosed DVD.

Acronyms and Abbreviations

Allied OU	Allied Paper, Inc. Operable Unit
AMSL	above mean sea level
AOC	Administrative Order by Consent
ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing & Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BBEPC	Blasland & Bouck Engineers, P.C.
BBL	Blasland, Bouck & Lee, Inc.
bgl	below ground level
bgs	below ground surface
BERA	Baseline Ecological Risk Assessment
CDM	Camp Dresser & McKee Inc.
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
cfs	cubic feet per second
CLP	Contract Laboratory Program
cm/s	centimeters per second
COC	contaminant(s) of concern
COD	chemical oxygen demand
cy	cubic yard
DCS	Description of the Current Situation
DO	dissolved oxygen
DOC	dissolved organic carbon
ºF	Fahrenheit
FEMA	Federal Emergency Management Agency
FML	flexible membrane liner
FRDL	former residuals dewatering lagoons
FS	Feasibility Study
FSP	Field Sampling Plan
ft	feet
GDC	geosynthetic drainage composite
Gpm	gallon per minute
GSI	groundwater-surface water interface
H:V	horizontal to vertical
HHRA	Human Health Risk Assessment
HRDL	historical residuals dewatering lagoon
IRM	Interim Response Measure
ISWS	Illinois State Water Survey
K	hydraulic conductivity
K_h	horizontal direction
K_v	vertical direction
K_{oc}	organic carbon partitioning coefficient
K_{ow}	octanol-water partitioning coefficient
LDPE	low-density polyethylene
LOAEL	lowest observed adverse effect level
LTM	Long-Term Monitoring
MHLLC	Millennium Holdings, LLC.

MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
meq/L	milliequivalents per liter
mg/kg	milligrams per kilogram
MSU	Michigan State University
mV	millivolt
NCASI	National Council of the Paper Industry for Air and Stream Improvement
NCP	National Contingency Plan
NEA	Northeast Analytical Laboratory
ng/L	nanograms per liter
NGVD	national geodetic vertical datum
NOAEL	no observed adverse effect level
NREPA	Michigan Natural Resources and Environmental Protection Act
NTU	nephelometric turbidity unit
NWI	National Wetland Inventory
ORP	oxidation-reduction potential
OU	Operable Unit
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyls
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzofurans
POTW	publicly-owned treatment works
ppb	parts per billion
ppm	parts per million
psf	pounds per square foot
PUF	polyurethane foam
PVC	polyvinyl chloride
QAO	Quality Assurance Officer
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RBC	Risk Based Criteria
RI	Remedial Investigation
RI/FFS	Remedial Investigation/Focused Feasibility Study
RRD	Remediation and Redevelopment Division
SARA	Superfund Amendments and Reauthorization Act
SOW	scope of work
SOW	Statement of Work
SVOC	semivolatile organic compounds
SRSL	Secondary Risk Screening Level
STL	Severn Trent Laboratories
TAL	Target Analyte List
TCL	Target Compound List
TDS	total dissolved solids
TEF	toxicity equivalence factors
TOC	total organic carbon
TSS	Total Suspended Solids
μg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
USDA	U.S. Department of Agriculture

USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
UU	Unconsolidated-Undrained
VOC	volatile organic compounds

1. Introduction

1.1 Scope and Objectives of the Remedial Investigation

This report presents the findings of the Remedial Investigation (RI) conducted at the Allied Paper, Inc. (Allied) Operable Unit (OU) which is located in Kalamazoo, Michigan. Blasland, Bouck & Lee, Inc. (BBL) conducted the RI on behalf of Millennium Holdings, LLC. (MHLLC) (the successor to HM Holdings, Inc.) pursuant to an Administrative Order by Consent (AOC) (Final Order No. DFO-ERD-91-001) issued by the Michigan Department of Natural Resources (MDNR) [1] (MDNR, 1991) for the Allied Paper, Inc./Portage Creek/Kalamazoo River (Kalamazoo River) Superfund Site. On October 25, 2006, the Michigan Department of Environmental Quality (MDEQ) disapproved the Draft report and exercised its ability to author this RI pursuant to paragraph 30 (D) of the AOC (MDEQ, 2006). This report (including figures, tables, and appendices) was written by modifying the supplied BBL draft report.

The RI was conducted in accordance with the AOC and consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR Part 300, Subpart E), the Michigan Natural Resources and Environmental Protection Act (NREPA; Act 451, Part 201), and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1996. The RI was completed in accordance with the *Allied Paper, Inc. Operable Unit Remedial Investigation/Focused Feasibility Study Work Plan* (*RI/FFS Work Plan*) (Blasland & Bouck Engineers, P.C. [BBEPC], 1993a) and other work plans developed pursuant to the AOC Statement of Work (SOW) for the Kalamazoo River Superfund Site and approved by the MDNR/ MDEQ. The scope of work described in the initial RI/FFS work plan was expanded during the RI activities. The additional tasks were performed pursuant to work plans approved (either explicitly or implicitly) by the MDEQ, as summarized below. MDEQ provided both input and oversight in the field for the majority of activities.

[1] In 1995, the environmental quality divisions of the MDNR were reorganized into the MDEQ.

Work Plans and Approval Dates

Work Plans	Submittal Date
Allied Paper, Inc. Operable Unit Remedial Investigation/Focused Feasibility Study Work Plan	6/15/1993
Quality Assurance Project Plan for the RI/FS for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site, Kalamazoo, Michigan	2/1/1993
Addendum to RI/FFS Work Plan	9/15/1995
Addendum II to RI/FFS Work Plan	2/13/1997
Addendum III to RI/FFS Work Plan	6/11/1997
Allied Paper, Inc. Operable Unit Monitoring Well Installation	3/3/1998
Geotechnical Sampling at Allied Paper, Inc.	8/1/1998
Proposed Well Abandonment	10/2/1998
Sediment Probing Plan	7/12/1999
Bryant HRDL/FRDLs Closure Allied Paper, Inc. Operable Unit Engineering Design Report - Sedimentation Pond and Liner Installation	8/19/1999
Bryant HRDL/FRDLs Closure Allied Paper, Inc. Operable Unit Engineering Design Report - Sheetpile Design	8/19/1999
Well Rehabilitation and Abandonment Plan	7/22/1999
Groundwater Extraction in Conjunction with the Sheet Piling Installation	2/9/2000
Residuals Removal Work Plan	3/10/2000
Installation of Permanent Sumps PS-1 through PS-5 and Drainage Trench	6/27/2000
Anticipated Groundwater Monitoring Network Modifications	8/14/2000
Allied Paper Operable Unit: Bryant HRDL/FRDLs Final Cover	8/19/1999
Installation of Temporary Sumps	6/27/2000
Proposal for Investigation of the Clay Seam Located on the Eastern Bank of Portage Creek	12/18/2000
Proposal for Sampling East Bank Face of Portage Creek	8/6/2001
Proposal for Characterizing Residuals along Portage Creek	10/24/2001
Additional Work to Complete IRM and RI – Residuals Delineation and Monitoring Well, Observation Well, and Soil Boring Installation	5/2/2002
Groundwater Seeps Investigation Work Plan	8/29/2002
Additional Work to Complete IRM and RI – Perimeter Soils Excavation	5/2/2002
Work Plan for Additional RI Studies	12/27/2002
2003 Q-1 Groundwater Sampling Program	4/17/2003

Early investigative efforts recognized that if the full extent of polychlorinated biphenyls (PCBs) was identified and appropriately remediated, then other associated hazardous substances at this or any other OU would be appropriately addressed. Therefore, this RI is mainly focused on identifying the known extent of PCBs at the Allied OU. However, data exists for other hazardous substances which have been considered in this report.

The primary objectives of the RI for the Allied OU are to: (1) assess the nature and extent of PCBs and other hazardous substances, to the extent they were evaluated, that may be present in air, soil, sediment, surface water, groundwater, and leachate; and (2) evaluate the potential threat to public health, welfare, or the environment caused by the release or threatened release of hazardous substances, pollutants, or regulated substances from the OU. Corollary objectives of the RI are to:

- Characterize the OU topography, drainage, geology, hydrogeology, meteorology, wetlands, and biota, as well as the surrounding population and nearby land use;

- Characterize the constituents listed on the Contract Laboratory Program (CLP) Target Compound List (TCL) (volatile organic compounds [VOCs], semivolatile organic compounds [SVOCs], pesticides, and PCBs), polychlorinated dibenzo-p-dioxins (PCDD)/polychlorinated dibenzofurans (PCDF), and Target Analyte List (TAL) that are present at levels exceeding appropriate regulatory thresholds, and which are attributable to the OU;

- Provide information sufficient to evaluate potential pathways for environmental and human exposure to PCBs and other hazardous substances; and

- Collect data necessary to develop and evaluate remedial alternatives.

This RI report documents the conditions at the Allied OU both before and after completion of the 1998-1999 U.S. Environmental Protection Agency (USEPA) Time Critical Removal Action (Removal Action) at the Former Bryant Mill Pond. Some of the field investigations described in this RI were completed during the performance of an Interim Response Measure (IRM) conducted by MHLLC in the area of the Bryant historical residuals dewatering lagoon (HRDL) and former residuals dewatering lagoons (FRDLs) to secure the materials USEPA removed from the Former Bryant Mill Pond. The Removal Action and the IRM modified conditions at the Allied OU, and sampling efforts during and after these activities yielded additional site characterization data. This report provides all of the information on which the current conceptual model for the OU is based.

1.2 Description and Background

The Allied OU is located within the city of Kalamazoo, which as of 2000 had a population of approximately 77,000 people (US Census Bureau, 2003). The Allied OU includes areas that are zoned for industrial, commercial, and residential purposes. Residential development exists along a portion of the east side of the OU and to the west beyond the railroad tracks. Industrial and commercial properties are located north and south of the OU and along portions of the east and west side of the OU. The OU is defined as areas between Cork Street and Alcott Street where contamination from paper operations have come to be located. A more detailed description of the physical setting of the Allied OU and nearby environs is presented in the *Description of the Current Situation* report (*DCS*) (BBEPC, 1992).

Descriptions of the various study areas and the OU, and a summary of the operational history of the mills associated with the OU are presented in Section 1.2.1 and Section 1.2.2, respectively. The OU cleanup activities completed to date are summarized in Section 1.2.3.

1.2.1 Description of the Operable Unit

The Allied OU, one of four land-based OUs associated with the Kalamazoo River Superfund Site, is located along Portage Creek within the city of Kalamazoo in Kalamazoo County, Michigan (Figure 1). The Allied OU encompasses 89 acres along Portage Creek between Cork and Alcott streets. As described in more detail in Section 1.2.2, the Bryant Paper Mills were built by the Bryant Paper Company in 1895 and various paper manufacturing and disposal operations were conducted on the site until all paper manufacturing operations ceased during the late 1970s and early 1980s. No active mills remain on site.

The Alcott Street dam was built in 1895 to provide mechanical power and process water for the paper mill and impounded Portage Creek to form the Bryant Mill Pond. Allied Paper Company obtained a permit (NO. 75-12-187) from the MDNR to draw down the reservoir in 1976 in an effort to reduce the BOD loading to Portage Creek. The dam was owned and operated by the Allied Paper Corporation of Kalamazoo, Michigan (USACE, 1979). The reservoir drawdown narrowed the creek channel and exposed sediments that had accumulated over the many years of mill operations. The earthen dam is currently owned by Millennium Holdings, Inc. and is classified as a high hazard structure by MDEQ Land and Water Management Division. It impounds surface water and sediment within the channel of Portage Creek, but at an elevation approximately 13 feet (ft) lower than before the opening of the gates. The dam was last inspected in May 2006 and the next inspection is scheduled for December 2009 (MDEQ, Michigan Dam Inventory database).

Paper-making residuals (residuals) were the primary waste product generated during the paper recycling process at the mills. These residuals, which are primarily a mixture of clay and wood fiber, often appear at the site as deposits of gray clay. As with most clays, the residuals have low permeability when compacted. The visual appearance of residuals is distinctive, and a goal of some excavation activities has been to remove all the gray clay residuals.

PCBs were introduced to the OU through the recycling of carbonless copy paper that contained PCBs as a carrier for the ink. Carbonless copy paper contained PCBs between 1957 and 1971 and PCBs were in the recycle stream after that period as the carbonless copy paper supply was depleted.

To aid in site characterization and remedial planning efforts, the Allied OU was divided into individual study areas based upon historic operations as follows (see Figure 2):

- **Former Operational Areas** (Bryant HRDL and FRDLs, Monarch HRDL, Type III Landfill, Western Disposal Area, and the Alcott Street Properties).

    - Bryant HRDL and FRDLs: These six lagoons, covering an area of approximately 22 acres, were used to settle out residuals from the wastewater generated at the Bryant Mills. A clarifier and the earthen-diked HRDL were the primary treatment system, built in 1954. The series of five FRDLs were added later to dewater residuals. The HRDL was filled and has been inactive since the late 1970s, and the FRDLs have been inactive since 1989 (BBEPC, 1992).

    - Monarch HRDL: This 7-acre lagoon was used as part of the initial primary treatment facility for process waste from the Monarch Mill. The facility consisted of a clarifier and an earthen-diked dewatering lagoon. After clarification, the wastewater supernatant was discharged to Portage Creek and the settled residuals were pumped to the Monarch HRDL for dewatering. The Monarch HRDL was used from the early 1950s until the 1960s.

    - Type III Landfill: This 13-acre area was originally licensed as a landfill in 1966 to receive non-process wastes pursuant to former Act 87, Public Act of 1965. It was then licensed as a Type II Landfill at the inception of former Act 641 in 1978, the designation was changed to a Type III landfill in 1985 to receive residuals and demolition wastes. Over the period of use (1966 until the late 1980s), the landfill area received various types of industrial waste and residuals. The landfill area is located in the center of the OU, just south of the former Bryant Mill Pond.

    - Western Disposal Area: The Western Disposal Area, covering approximately 19 acres, is located along the western edge of the Bryant HRDLs, southwest of the Former Type III landfill. The area stretches from the Panelyte Marsh south to Cork Street. Based on the interpretation of aerial photographs taken in 1967, 1974, 1978, 1981, 1986, and 1991 and personal conversations with Allied employees, for a period of time, the area was used as a disposal area for dewatered residuals mined from the HRDL and FRDLs. By 1986, most of the area, with the exception of a borrow pit, appeared to be filled in, and vegetation had been reestablished by 1991 (BBEPC, 1993a).

- Alcott Street Properties: The Alcott Street Properties comprise two areas near Alcott Street that are on MHLLC property. These two areas have a limited operational history and therefore little data was collected.

- **Former Bryant Mill Pond:** Allied Paper Inc. deinked and recycled large amounts of wastepaper at the Bryant Mill A. From the 1950s until 1971, carbonless copy paper was a component of the wastepaper stream and was subsequently deinked at the Allied facility which resulted in the release of PCBs to the mill pond. Until the 1950s, untreated process waste was discharged directly into Portage Creek. In the 1950s, clarifiers and dewatering lagoons for the Monarch and Bryant mills were constructed as a treatment for the process waste intended to settle out fine material prior to its discharge to Portage Creek. Particles in the wastewater discharged from the mills to Portage Creek settled out in the 29-acre Bryant Mill Pond. USEPA conducted a removal action in the area in 1998 and 1999 (see Section 1.2.3.1) to address PCBs in the sediment. When the Alcott Street Dam gates were lowered in 1976 and the water was confined to the narrower creek channel, areas of sediment were exposed that have since revegetated (BBEPC, 1992).

- **Residential/Commercial Areas** (Including but not limited to, Former Panelyte, Stryker Corporation, Conrail, Clay Seam Area, East Bank Area, and Other Properties).

  - Panelyte Property and Marsh: Located along the northwestern border of the Former Bryant Mill Pond, this area encompasses approximately 23 acres and contains a fill area, located at the southwestern end of the property. This property is a Brownfield site and is currently being managed by the MDEQ. The Panelyte Marsh is located at the southeastern end of the Panelyte property, north of the Western Disposal Area. Surface water from the Panelyte fill area and Western disposal area drains towards the Panelyte Marsh.

- Stryker Corporation Property: Stryker Corporation owns a business located along the northeast border of the Former Bryant Mill Pond. The parking lots on the Stryker property were constructed over parts of the Former Bryant Mill Pond.

- Conrail Property: The Railroad property that extends along the western edge of the OU.

- Clay Seam Area: The clay seam is a body of residuals covering approximately a quarter of an acre that is present as a small, nearly vertical bluff on the east side of Portage Creek, across from the Bryant FRDL #1 and off MHLLC property. Native soils appear to underlie the clay seam at the elevation of the water line. The clay seam extends up to approximately 80 ft inland from the bank of Portage Creek.

- East Bank Area: Covering less than a quarter of an acre, this former area of residuals is located across from the Bryant HRDL on the east bank of Portage Creek. The residuals deposit extended approximately 80 ft inland from the bank of the creek. These residuals were removed in 2002 during the IRM and replaced with clean fill material.

- Other Properties: (Consumers Power, Golden Age, City of Kalamazoo, Former Raceway Channel, and various residential properties). Because contamination from paper operations came to be located on several individually owned properties used for commercial, industrial, or residential purposes, investigation activities extended onto these areas as well.

1.2.2 Background and Operational History

Paper mills became an important part of the Kalamazoo River Valley in the late 1800s. For the first 50 to 60 years, most of the mills made paper products from virgin pulp. Starting in at least the 1950s, the mills in the Kalamazoo area began to recycle waste paper for stock (Walters, 2001). Mixed in with the paper sent to the mills for recycling was carbonless copy paper produced by NCR, which between at least 1957 and 1971, contained PCBs as an ink carrier. Carbonless copy paper was not manufactured at any of the mills in the Kalamazoo River Valley.

When mills recycled waste paper that included carbonless copy paper, PCBs were present in the wastewater produced from the recycling process. Typically, the wastewater contained large quantities of suspended particles – primarily cellulose and clay. PCBs were present in the recycling process from at least 1957 until well after production of carbonless copy paper containing PCBs stopped in the 1970s. The solid components of the recycling process adsorb or contain high concentrations of PCBs. In the 1950s, mills began building clarifiers and dewatering or settling lagoons to remove most of the particles, and the clarified wastewater was discharged to rivers and creeks (in this case, Portage Creek). At the Allied OU, the legacy of this practice is PCB-containing materials in the Monarch and Bryant HRDLs and FRDLs, and since Portage Creek was impounded by the Alcott Street Dam, the materials also settled out in the Former Bryant Mill Pond. These PCB-containing materials, referred to in this report as residuals, have been the focus of the investigations conducted at the Allied OU.

A description of the operational history of the mills associated with the Allied OU is presented in the *DCS* (BBEPC, 1992). A brief summary of that information is presented below.

The Bryant Mills (A, B, C, D, and E) were built by the Bryant Paper Company in 1895 and produced a variety of high-quality paper products for the next 94 years. The St. Regis Paper Company owned and operated the mills (with the exception of the coating mill), starting in 1946. Allied leased the mills from St. Regis Paper Company from 1956 to 1966, before purchasing them in 1966. Mill B was no longer active when Allied began operations. The coating mill was purchased by Panelyte in 1949. Allied sold Mill A to American Pulp Corporation in 1972, and the building was demolished around 1978. In 1989, Allied sold the other mill buildings to Performance Paper, Inc., who ceased operations in 1989. The Monarch Mill was built by the Kalamazoo Paper Company in 1875. Allied acquired the Monarch Mill in 1922, and operated it until 1980, when it was closed and razed (BBEPC, 1992).

Raw materials used in the production process at the Bryant Mills included virgin pulp as well as recycled paper. Starting in the mid-1950s, Allied de-inked and recycled paper at Bryant Mill A, located south of Alcott Street along the Former Bryant Mill Pond. The buildings and operational areas of the Allied OU are identified in aerial photos from 1938, 1950, 1955, 1960, 1967, 1974, 1978, 1981, 1986, and 1991 as presented in the *DCS* on Figures 27 through 36 (BBEPC, 1992). Presumably, some portion of the paper that Allied recycled at Bryant Mill A contained carbonless copy paper; therefore, from as early as 1957 until at least 1971, the process solid waste, which consisted mainly of residuals, contained PCBs. Bryant Mills B, C, D, and E were not used for de-inking or recycling operations. De-inked stock was used briefly at the Monarch Mill, but by 1957 only virgin fiber was being used.

Allied constructed a primary treatment facility in the early 1950s for the former Monarch Mill to treat solids in wastewater. The treatment facility, which was the first of its kind in the area (BBEPC, 1992), consisted of a clarifier and an earthen-bermed dewatering lagoon, now referred to as the Monarch HRDL (Figure 2). Wastewater from the mill was sent to the clarifier. After clarification, the settled residuals were pumped to the Monarch HRDL for dewatering. The Monarch HRDL has not been an active residuals disposal area since the 1960s (Wilkins & Wheaton, 1986).

The St. Regis Paper Company, the operator of the Bryant Mills from 1946 until 1956, installed a similar treatment system for the Bryant Mills in 1954 (BBEPC, 1992). The system consisted of the Bryant Clarifier and the earthen-bermed Bryant HRDL located north of Portage Creek. The FRDLs were added to the system by 1960 (there is no functional difference between the FRDLs and HRDLs). Aerial photographs (BBEPC, 1992) appear to indicate that residuals continued to be disposed of in the Bryant HRDL until the late 1970s, in the Western Disposal Area until the early to mid 1980s, and in the Bryant FRDLs until the late 1980s.

In 1966, under Act 87, Public Act of 1965, Allied began operation of a landfill for non-process industrial wastes (such as cardboard, packing strips, waste paper, and demolition materials) in the area north of the Bryant HRDL and FRDLs. The landfill then became subject to and licensed under the former Act 641 in 1978 and was classified as a Type II Landfill. The classification was subsequently changed to Type III (Industrial Waste) in September 1984. The change in classification required that deposited wastes be primarily residuals or “paper mill sludge” along with some construction and demolition waste. Written approval was required to dispose of any other type of materials. In May 1987, Allied's application for renewal of the license was denied based on the MDNR's determination that wastes were present outside of the area covered by the license. In July 1987, Allied submitted a second landfill license renewal application to the MDNR. The second application was denied because it was determined to be incomplete, and the MDNR requested additional investigations and development of a remedial action plan to address the areas later defined as the OU. Allied began site investigations, and in December 1988 the investigation requirements were incorporated into a partial Order by Consent between Allied and the State, which allowed Allied to continue to operate the landfill as long as compliance with the Order was maintained (BBEPC, 1992). Investigations continued until 1990, at which time Allied entered into the AOC for the Kalamazoo River Superfund Site. Disposal to the landfill ceased in the late 1980s, and the landfill license is no longer active.

1.2.3 Completed Response Activities at the Allied OU

The Allied OU was designated as a distinct unit within the Kalamazoo River Superfund Site so cleanup activities could precede on a separate time table from the remedial activities developed for the site as a whole. In 1998 and 1999, the USEPA completed the Removal Action at the Former Bryant Mill Pond to address PCB-containing sediments in that area. MHLLC then began a series of response activities (collectively called the IRM and depicted on Figure 3) to stabilize the area where USEPA disposed of the materials excavated from the Former Bryant Mill Pond and to address other areas that were potential sources of PCBs to Portage Creek and the Kalamazoo River. Both the Removal Action and the IRM, which are described below, were implemented to reduce the amount of PCBs that migrate from the OU to the river and creek.

1.2.3.1 Removal Action at the Former Bryant Mill Pond

Following the collection and review of RI data in 1997, the USEPA evaluated the need for response activities at the Former Bryant Mill Pond area of the Allied OU. As reported in the *DCS* (BBEPC, 1992), PCB concentrations ranged from non-detect to 1,000 milligrams per kilogram (mg/kg) in samples of exposed sediment collected from the Former Bryant Mill Pond at depths ranging from zero to 10 feet.

On June 2, 1998 the USEPA, the Department of Justice, and MHLLC entered into an Administrative Agreement under which MHLLC provided funding for the USEPA to conduct a time-critical Removal Action (USEPA, 1998a and b). The MDEQ concurred with the Removal Action, but noted its preference for lower remedial action criteria than that established by USEPA in an April 1998 letter (Cornelius, 1998a).

The USEPA prepared a work plan (Weston, 1998a) and amendments to the work plan (Weston, 1998b; 1998c) to document the methods to be used and activities to be completed for the Removal Action. Mobilization and clearing and grubbing began in June 1998. Excavation commenced in October 1998 and was completed in May 1999. Final demobilization was completed on September 23, 1999 (Weston 2000). The Removal Action involved the excavation of approximately 146,000 cubic yards (cy) of PCB-containing sediment, residuals, and soil from the Former Bryant Mill Pond and placement of these materials into the Bryant HRDL and FRDLs (Figure 2). The U.S. Army Corps of Engineers (USACE) performed this action under contract to the USEPA. The initial excavation was performed with an action level of 10 mg/kg, and a goal of achieving post-excavation PCB concentrations less than or equal to 1 mg/kg. At locations where post-excavation sampling results exceeded this goal, an additional six inches of material was removed. The USACE backfilled the excavated area with an amount of clean fill approximately equal to the volume of sediment, residuals, and soil removed. The surface of the materials placed in the Bryant HRDL and FRDLs was graded to a slope designed to be greater or equal to two percent, acknowledging future consolidation.

As stated in the final Bryant Mill Pond Administrative Agreement, "The Bryant Mill Pond Area Removal Action is intended to be consistent with what EPA anticipates will be the final remedy to be selected by MDEQ." The vast majority of post-excavation samples were below the target PCB concentration of 1 mg/kg (Weston, 2000). The nature and extent of PCB contamination at this OU was significantly reduced by the Removal Action and this RI has been structured to acknowledge this work.

1.2.3.2 Interim Response Measure

In the early to middle 1990s, MHLLC conducted a series of small-scale IRM activities to restrict access to the site and provide erosion control and stabilization in certain areas. After completion of the Removal Action, MHLLC carried out a number of large-scale IRM activities to further mitigate the transport of, or exposure to, PCBs at the Allied OU. Figure 3 depicts the various components of the IRM, which include:

- Installation of approximately 2,600 linear feet of sealed-joint sheetpile along the west bank of Portage Creek to stabilize the perimeter berms that separate the Bryant HRDL and FRDLs from the Portage Creek floodplain. This response action was completed in 2001.

- Construction of a landfill cap for the Bryant HRDL and FRDLs was intended to be designed in accordance with the requirements of Michigan Act 451, Part 115 solid waste regulations. The cap design consists of six layers from the bottom of the cap to the top (at the ground surface). The layers are: a non-woven geotextile, a 12-inch thick (minimum) sand gas venting layer, a 30-mil polyvinyl chloride (PVC) flexible membrane liner (FML), a geosynthetic drainage composite (GDC) layer, a 24–inch thick (minimum) drainage and soil protection layer, and 6–inch thick (minimum) vegetated, topsoil layer. This cap, which covers the Bryant HRDL and FRDLs, was constructed between 2000 and 2004. The FML liner installation commenced in 2000, however, portions of the liner were left exposed to the elements prior to completion of the cap in 2004. The FML was left exposed for substantial time periods and MDEQ requested that these areas be replaced due to ultraviolet and physical damage. MHLLC elected to make over 1000 repairs to the cap in lieu of the requested replacement.

- Design and installation of a groundwater recovery system to mitigate mounding of shallow groundwater (above the peat unit) behind the sheetpile installed in the berm along Portage Creek. The groundwater recovery system includes two recovery wells (GWE-1A and GWE-4A) and ten sumps – six that drain a series of horizontal recovery trenches (PS-1 through PS-5, and PS-9) and four individual sumps (PS-6, PS-7, PS-8, and PS-10) along the sheetpile. The water, which contains contaminants (see Table 4-4M), recovered by this system is currently treated on-site by an activated carbon treatment system and discharged to the city of Kalamazoo publicly-owned treatment works (POTW) in accordance with a wastewater discharge permit.

- Removal of several hundred cubic yards of soil containing residuals from locations between the sheetpile wall and Portage Creek, and consolidation into the Bryant HRDL and FRDLs, now under a landfill cap. This material was removed in 2000 and 2003 to minimize the potential for PCB releases to Portage Creek.

- Removal of approximately 1,700 cy of residuals located within the floodplain on the east side of Portage Creek (East Bank area) in 2002, and consolidation into the Bryant FRDLs under the landfill cap.

The IRM is described in detail in Appendix F.

1.3 Transition of Regulatory Management

On February 15, 2002 the MDEQ and USEPA Region 5 executed a site-specific amendment to the 1989 Superfund Memorandum of Agreement for the Kalamazoo River Superfund Site that provided for a transition of regulatory management for the Allied OU to federal lead after the MDEQ approves the RI Report. The reasons for this amendment, which was requested by the MDEQ, are explained in a letter from Russell Harding, Director of MDEQ, to David Ulrich, Acting Regional Administrator of USEPA Region 5 (Harding, 2001).

1.4 Scope of the RI Report

The scope of this RI report is to describe the nature and extent of contamination at the Allied OU. This RI report is the most recent in a series of technical memoranda and reports that have been prepared to document activities. RI field and analytical data, as well as a quality assurance/quality control (QA/QC) review of the data, for activities conducted from 1993 to 1999 are reported in the technical memoranda listed below. The relevant results and findings of the activities described in these technical memoranda, as well as in the reports developed by government contractors, are summarized in this RI report. The later investigations (i.e., those conducted after December 1999) have not been described in previous reports, and are provided in this report.

- *Technical Memorandum 4 - Allied Paper, Inc. Operable Unit Results of the Air Investigation* (BBL, 1994a) is a record of air quality data collected during the RI. Approved April 8, 1994.

- *Technical Memorandum 7 - Allied Paper, Inc. Operable Unit* (BBL, 1997c) provides characterization data for soil, sediment, residuals, and surface water as well as the initial phase of groundwater sampling collected during the RI. (Note that these data were collected prior to the Removal Action and IRM.). Approved August 21, 1997.

- *Addendum to Technical Memorandum 7 - Allied Paper, Inc. Operable Unit* (BBL, 1999) is a record of the supplemental groundwater sampling and analysis performed from 1995 to 1998 at the Allied OU. This report, which was approved on July 5, 2000, includes the results of six additional phases of groundwater sampling.

- *Technical Memorandum 11 - Allied Paper, Inc. Operable Unit Biota and Surface Water Investigations and Wetlands Assessment* (BBL, 2000a) is a record of the surface water investigation, biota investigation, and wetlands assessment performed from 1993 to 1994 for the RI at the Allied OU. The surface water investigation and wetland assessment information presented in *Technical Memorandum 11* relates primarily to the Former Bryant Mill Pond area of the Allied OU prior to the removal of PCB-containing sediments by the USEPA in 1998-1999 (described in further detail in Section 1.2.3.1 of this report). The findings discussed in *Technical Memorandum 11* (BBL, 2000a), therefore, represent historical conditions of the Former Bryant Mill Pond and Portage Creek at the Allied OU. Approved July 5, 2000.

- *Technical Memorandum 13 - Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Water Well Inventory* (BBL, 1995b) provides information on water well distribution and usage along Portage Creek and the Kalamazoo River. Approved April 7, 1995.

This RI report also incorporates relevant information compiled by MDEQ, the Michigan Department of Community Health (MDCH), and government contractors. Both the MDEQ and MDCH have collected fish from Portage Creek. The MDEQ initiated a Long Term Monitoring (LTM) Program in 1999, and the MDCH manages the Michigan Fish Contaminant Monitoring Program. Information on these efforts and applicable results are discussed in Section 2 and Section 4, respectively. The activities conducted and data obtained during the USEPA Removal Action in the Former Bryant Mill Pond area of the site in 1998 – 1999 are presented in the *Final Report – Allied Paper/Portage Creek/Kalamazoo River Superfund Site* (*Final Report*) (Weston, 2000). Wetland areas at the Allied OU are delineated and described in the *Kalamazoo River and Portage Creek Wetland Delineation Study* (Camp Dresser & McKee Inc. [CDM], 2002a), which also provides similar information for other reaches of the Superfund Site.

2. OU Investigation Activities

The investigative activities, which were conducted as described in the RI/FFS Work Plan (BBEPC, 1993a) and addenda, included the following:

- Air Investigation;
- Soils Investigation;
- Hydrogeological Investigation;
- Sediment Investigation;
- Surface Water Investigation;
- Biota Investigation; and
- Wetlands Assessment.

While all investigations conducted to date are discussed in this report, the activities are described in varying levels of detail. A number of investigatory efforts were completed prior to the Removal Action and the IRM (described in Section 1.2.3.1 and Section 1.2.3.2, respectively). Because these response actions significantly changed conditions at the OU, results of the earlier investigations no longer adequately characterize the current situation. Further, the earlier investigations are fully described in *Technical Memoranda 4, 7 (and its addendum),* and *11*(BBL 1994a, 1997c, 1999, and 2000a). As a result, the activities completed prior to the Removal Action and the IRM are simply summarized here. The investigations conducted since 2000 and those that have not been described in previous reports are discussed in more detail in this Section since their results can be used to assess existing conditions at the site. The results of physical characterization from all of the investigations (early and recent) are summarized in Section 3, and the results of all of the chemical analyses are summarized in Section 4 of this report. Supporting BBL and CDM field documentation for the more recent investigations are included in Appendix A and Appendix MDEQ – A, respectively.

In all of these investigations, samples were collected in the manner prescribed in the *Allied Paper, Inc. Operable Unit RI/FFS Field Sampling Plan* (*FSP*) (BBEPC, 1993b) and analyzed in accordance with the procedures described in the *Quality Assurance Project Plan* (*QAPP*) (BBEPC, 1993c), as approved by the MDEQ prior to the RI field activities (Cornelius, 1993a and b).

2.1 Air Investigation

The objective of the air monitoring program was to assess potential emissions of PCBs along the perimeter of the OU during a period when the potential for such emissions would be greatest. In accordance with USEPA guidance (USEPA, 1988) and the *RI/FFS Work Plan* (BBEPC, 1993a), worst-case conditions were monitored by collecting air samples during high-temperature months (June through August 1993) and analyzing them for PCBs. Twenty-four-hour composite air samples were taken every sixth day from five air samplers (AP-1 through AP-5) placed in the vicinity of the OU (Figure 4). In addition, two air samplers (BC-1 and BC-2) were placed in the city of Battle Creek to assess background PCB concentrations in an urban Michigan environment. The meteorological station erected at the Allied OU recorded ambient wind speed and direction, air temperature, solar radiation levels, relative humidity, and precipitation. Concurrently, meteorological data for the OU were collected from an on-site meteorological station located east of the Bryant Clarifier. A summary of the air samples collected at the Allied OU and the background locations in Battle Creek is presented in Table 2-1. The meteorological monitoring results of the air investigation are presented in Section 3.2.1, and the results of chemical analysis of air samples are presented in Section 4.1. Further details regarding the methods and findings of the Air Investigation are reported in *Technical Memorandum 4* (BBL, 1994a).

2.2 Soils Investigation

The investigations were conducted to chemically and/or physically characterize:

- Materials within and native soils below the berms of the Bryant and Monarch HRDLs and FRDLs; and
- Soils and residuals in each of the study areas.

Activities conducted for the Removal Action and IRM (described in Section 1.2.3.1 and Section 1.2.3.2, respectively) have significantly altered site conditions. As a result, many of the findings of the early RI characterization efforts no longer represent current conditions. The following sections present information on the entirety of investigative activities conducted to complete the soil and residuals investigation; however, greater attention is given to those more recent activities that yielded information that describes the present situation.

As reported in Section 5.1.1 of the *DCS* (BBEPC, 1992), information regarding the characterization of soil and residuals that was gathered during investigations conducted prior to the completion of the DCS, was used to guide and narrow the subsequent investigative efforts described in this report. These efforts were carried out in several phases between 1993 and 2003 to characterize soil and residuals at the Allied OU. Soil borings for the investigations were drilled throughout the study areas using a variety of methods, including truck-mounted rig with hollow-stem auger, tripod-mounted driven casing, hand-driven split-barrel sampling, and hand auger. Selected soil samples were collected and analyzed for one or more of the following parameters: PCBs, CLP TCL/TAL, or PCDD/PCDF.

Table 2-2 presents a summary of all the soil and residuals samples submitted for chemical analysis during the various investigation phases. Over the past 10 years, 383 samples of soil and residuals have been collected from 144 locations at depths ranging from 0 to 56 feet below grade. These sample locations were biased away from certain areas (i.e. western disposal area, Type III Landfill, Monarch HRDL, etc.). The understanding of residuals contamination allowed for the assumption that the areas where residuals were disposed did not require extensive investigation since these areas were obviously impacted. Furthermore, these areas would be addressed by some future remedial activity identified in the Feasibility Study (FS). The soil sampling locations are shown on Figure 5, and logs for all the soil borings are included in Appendix B. The results of physical characterization of soil and residuals are presented in Section 3.2.4.2 and Section 3.2.4.4. The chemical characterization results are discussed in Section 4.2.

2.2.1 1993 – 1999 Soils Investigation

Soils and residuals were the focus of three investigations conducted between the beginning of the RI in 1993 and immediately after the completion of the USEPA Removal Action in 1999.

BBL drilled 38 soil borings during a comprehensive investigation in 1993. Each boring drilled typically was logged continuously from the ground surface to the boring terminus. Detailed information regarding the 1993 phase of soil and residuals characterization is presented in Section 2.1 and Section 2.5 of *Technical*

Memorandum 7 (BBL, 1997c). All of the boring logs from this investigation are provided in Appendix B of this report.

In 1997, soil borings were drilled for the installation of seven monitoring wells (MW-22AR, MW-24R, MW-25R, MW-122AR, MW-126AR, MW-5R, and P-1R). No samples of soil, fill, or residuals were submitted for chemical analysis; however, physical descriptions of subsurface conditions were obtained during continuous logging of these borings. Detailed information regarding the investigative methods of this activity is provided in Section 2.5 and Appendix C of the *Addendum to Technical Memorandum 7* (BBL, 1999). All of the boring logs from this investigation are provided in Appendix B of this report.

During the Removal Action in 1998-1999, the USEPA discovered residuals along the perimeter berm of the Bryant FRDLs. BBL collected six composite samples of the residuals (BBS-1 through BBS-6) and analyzed them for PCBs using Ensys field test kits with detection limits of 1 mg/kg and 10 mg/kg. These sampling locations were excavated during the Removal Action and IRM; therefore, the results of these chemical analyses are representative conditions prior to these activities. The data associated with those locations are referred to as excavated data in this report.

2.2.2 2000 – 2003 Soils Investigation

Investigations were conducted from 2000 to 2003 in study areas on site and at targeted off-site areas to characterize soils and residuals and delineate the extent of PCB-containing deposits. Field documentation for the soil and residuals characterization activities conducted from 2000 to 2003 by BBL and MDEQ is included in Appendix A and Appendix MDEQ – A, respectively. Detailed descriptions of the investigative methods of these phases of investigation are presented in Appendix C. The results of these investigations represent the data which best characterize the site for use in preparing a FS.

2.2.2.1 Study Area Soil Borings

Soil borings were drilled in the various study areas of the OU during five phases of investigation between 2000 and 2003. The majority of the soil borings were drilled in the area of the Bryant HRDL and FRDLs in association with the installation of wells to monitor groundwater conditions during and after construction of the IRM. Several additional soil borings were drilled at the Type III Landfill and Monarch HRDL during this period, both to characterize soil and groundwater, and to assess subsurface conditions for construction of a groundwater treatment plant.

As part of the IRM, sealed-joint sheetpile was installed around the Bryant HRDL and FRDLs beginning in February 2000. The MDEQ required that, in conjunction with the construction of the sheetpile, several observation wells be installed behind the sheetpile to monitor water levels and verify that groundwater did not mound behind the sheetpile. In accordance with a work plan submitted to the MDEQ on February 9, 2000 (Cowin, 2000a), BBL drilled soil borings for the installation of 17 observation wells (OW-1A, OW-1P, OW-2A, OW-2B, OW-2P, OW-3A, OW-3B, OW-3P, OW-4A, OW-5P, OW-6A, OW-6P, OW-7P, OW-8A, OW-9P, OW-10P, and OW-11P) along the full extent of the sheetpile wall in February and March 2000. Also in February 2000, BBL drilled six pilot borings (GWE-1, PB-1B, GWE-2, GWE-3, GWE-4, and GWE-5) to assess subsurface conditions and evaluate methods to control water levels behind the sheetpile. Each location was logged continuously from the ground surface to the boring terminus. Further details regarding well installation are presented in Section 2.4.3. Although no samples were collected from these borings for chemical analyses, soil samples from selected depth intervals were collected from the pilot borings for geotechnical analysis. Results are discussed in Section 3.2.4.4.

BBL conducted additional drilling in the Bryant HRDL and FRDLs area between May and October 2000 for the installation of two groundwater recovery wells (GWE-1A and GWE-4A), six new double-cased monitoring wells (MW-200A, MW-201B, MW-202B, MW-203B, MW-204B, and MW-205B), five new observation wells requested by MDEQ (OW-11A, OW-12A, OW-13A, OW-13B, and OW-13P), and replacements for seven monitoring wells that had been damaged during construction activities: MW-23R, OW-3AR, OW-3PR, OW-4AR, OW-7PR, OW-9PR, and MW-30R (installed to replace MW-30, a well located on the site but owned and monitored by the neighboring Strebor, Inc. facility).

A significant additional phase of investigation was conducted from May to July 2002 at the Bryant HRDL and FRDLs. This effort included the installation of soil borings for additional monitoring wells to satisfy an MDEQ request and to obtain geologic information. The 2002 soil borings were conducted in general accordance with a work plan (Cowin, 2002b) that provided for the installation of up to twelve soil borings. During the field activities, the MDEQ requested a number of additional borings be drilled. Upon completion of this phase of investigation, 31 soil borings were drilled; the locations are identified on Figure 5: soil borings SB-A, SB-B, SB-C, SB-D, SB-E, SB-F, SB-G, SB-H, SB-I, SB-100, SB-101, SB-102; pilot borings MW-208, MW-210, MW-213, and MW-214; and soil borings for monitoring wells MW-206A, MW-207, MW-208, MW-209,

MW-210, MW-211, MW-212, MW-213, MW-214, observation wells OW-4PR, OW-14P, OW-15P, OW-16P, and OW-17P, and leachate well FW-101. The soil borings were logged continuously, except for locations where nearby borings provided adequate subsurface information for certain depth intervals. The soil boring logs are included in Appendix B.

Separately, Limno-Tech, Inc. supervised the installation of seven geotechnical soil borings in August and November 2002 to determine subsurface conditions at two locations being considered for construction of a groundwater treatment plant: GTA-02, GTB-02, GTC-02, GTNE11-02, GTNW11-02, GTSW11-02, and GTSE11-02. The locations of these geotechnical soil borings are shown on Figure 7, and logs for the soil borings are included in Appendix B. Samples of soil from selected depths were submitted for geotechnical analysis, as discussed in Section 2.2.3.

At the end of 2002, BBL prepared a work plan (Cowin, 2002d) that included the advancement of soil borings in the Bryant HRDL and FRDLs, Monarch HRDL, Type III Landfill, and the Former Bryant Mill Pond in order to install new wells and obtain geologic information. The MDEQ provided approval of the work plan, conditioned upon clarifications in a February 14, 2003 letter (Bucholtz, 2003a). From January through April 2003, BBL monitored the installation of soil borings by Mateco Drilling Company of Grand Rapids, Michigan at 31 locations, as shown on Figure 5: SB-J, SB-K, SB-L, SB-N, SB-O; pilot borings MW-215PB, MW-216PB, MW-217PB, MW-218PB, MW-219PB, MW-220PB, MW-221PB, and MW-225PB; and soil borings for wells MW-215, MW-216, MW-217, MW-218, MW-219, MW-220, MW-221, MW-222, MW-223, MW-224, MW-225, MW-226, MW-227, MW-228, MW-229, MW-230, MW-231, and MW-232. The logs for these soil borings are included in Appendix B.

2.2.2.2 Delineation of PCB-Containing Soils

In May and June 2002, 63 soil borings were drilled to visually determine the vertical and lateral extent of PCB-containing soils and residuals at the Allied OU specifically in areas where these materials may extend into the various study areas. The residuals delineation sampling followed the general provisions of a work plan developed by BBL (Cowin, 2002b). The MDEQ did not formally approve the work plan, but agreed that gathering the additional information related to determining the extent of residuals was necessary to complete the RI (Bucholtz, 2002). The residuals delineation borings (RD-series) were advanced singly or along transects in the Monarch HRDL, Western Disposal Area, Type III Landfill, Former Bryant Mill Pond, and residential/commercial properties at locations selected to better define the lateral extent of residuals. The 63 residuals delineation borings are identified by the RD prefix (RD-1A, RD-1B, etc.) and are shown on Figure 5. Forty-five of the residual delineation borings were advanced using direct-push technology, two were drilled using hollow-stem auger, and sixteen were advanced using hand auger to depths approximately 2 to 4 feet beyond the elevation at which PCB-containing deposits were expected to be found. Subsurface information was recorded on boring logs, per the provisions of the *FSP* (BBEPC, 1993b). At the request of the MDEQ, samples of soil were selected from the borings and submitted to the project laboratory for PCB analysis to confirm visual observations of the presence or absence of residuals. Results are presented in Section 4.2.1.1, and logs for the soil borings are provided in Appendix B.

Field activities conducted in 2003 included the collection of four surface soil samples (DW-1, DW-2, DW-3, and DW-4) at the northeast perimeter of the Monarch HRDL (see Figure 5). The soil samples were collected pursuant to an MDEQ-approved work plan (Cowin, 2002d) to evaluate whether surface water, which historically drained through culverts on the Monarch HRDL, had impacted soils in downstream drainage ditches. Results are presented in Section 4.2.1.1, and field documentation for this sampling event by BBL and MDEQ is provided in Appendix A and Appendix MDEQ – A, respectively.

2.2.3 Geotechnical Sampling

Five phases of Geotechnical Investigation were conducted at the Allied OU from 1993 to 2003 to provide data to assess the stability of the perimeter berms of the disposal areas, determine the practicability of groundwater recovery using extraction wells, assess the physical properties of residuals for future capping considerations, and to evaluate subsurface conditions for construction of a groundwater treatment building. The geotechnical laboratory analyses and field testing performed during each of the five phases is summarized in Table 2-3 and described in this Section. The locations of all geotechnical samples are shown on Figure 7, and the results of the various analyses are summarized in Section 3.2.4.4.

The 1993 phase of the investigation was conducted in accordance with the *RI/FFS Work Plan* (BBEPC, 1993a) to obtain geotechnical data regarding the physical characteristics of residuals and berm material in the Bryant HRDL and FRDLs. The 1993 investigation activities were conducted from July through August 1993 and included evaluating piezometric data, collecting disturbed and undisturbed samples of residuals and soil, performing field vane-shear testing, and conducting geotechnical laboratory testing of selected samples of residuals and soil. Laboratory testing conducted during the 1993 investigation included (methods are listed in parentheses):

- Water content (American Society for Testing & Materials (ASTM) D2216);
- Atterberg limits (ASTM D4318);
- Grain-size analysis (with hydrometer) (ASTM D422);
- Specific gravity (ASTM D854);
- Organic content (ASTM D2974);
- Unit weight (EM 1110-2-1906);
- Shear strength testing using a Torvane;
- Unconsolidated-Undrained (UU) Strength Testing (ASTM D2850); and
- One-dimensional consolidation (ASTM D2435).

In addition, field vane-shear testing (ASTM D2573) was also performed at three locations. Details of the 1993 phase of the Geotechnical Investigation are presented in Section 2.2 of *Technical Memorandum* 7 (BBL, 1997c).

Geotechnical samples were also collected from the Bryant HRDL and FRDLs between December 1997 and January 1998 to obtain more data on the physical characteristics of the residuals at depth (i.e., settlement and in-situ strength characteristics) in the Bryant HRDL and FRDLs prior to the USEPA Removal Action activities. Thirteen borings were advanced in the residuals at soil boring locations H-1, H-3, H-6, F2-1, F5-1, and F5-3 as part of this investigation. These geotechnical samples were submitted for laboratory testing which included water content, Atterberg limits, specific gravity, organic content, and one-dimensional consolidation. Vane-shear testing was performed at three locations at various depths. Further information regarding the 1997-1998 phase of the Geotechnical Investigation can be found in correspondence to the MDEQ on July 1, 1998 (Brown, 1998b).

The third phase of the Geotechnical Investigation was conducted in February through April of 2000 in accordance with an MDEQ-approved scope of work (Cowin, 2000b). Specifically, several pilot borings depicted on Figure 7 were advanced along the interior of the sheetpile wall to evaluate subsurface conditions at the locations of groundwater recovery wells proposed as part of the IRM. Selected geotechnical samples from the shallow water-bearing unit were analyzed for particle-size gradation via sieve analysis (i.e., ASTM D422) to identify screened intervals that would result in groundwater recovery, and to provide information for the selection of appropriate screen slot sizes and filter pack materials. In addition, selected geotechnical samples from the underlying glacial till were analyzed by both sieve and hydrometer to determine grain-size distribution. Details of the 2000 Geotechnical Investigation are presented in correspondence to the MDEQ (McCune, 2000a, b, c, and d).

In 2002 during the fourth phase of the investigation, Limno-Tech, Inc. collected 28 geotechnical samples from seven soil borings (GTA-02, GTB-02, GTC-02, GTNE-02, GTSE-02, GTNW-02, GTSW-02) located in two general areas of the Allied OU being considered for construction of a groundwater treatment system. Selected geotechnical samples were analyzed for water content, Atterberg limits, specific gravity, organic content, unit weight, and one-dimensional consolidation.

The fifth phase of the Geotechnical Investigation was conducted in February and March 2003 in accordance with an MDEQ-approved work plan (Cowin, 2002d). Although six soil borings (SB-J, SB-K, SB-L, SB-M, SB-N, and SB-O) were drilled during this phase, most of the testing was focused on borings SB-L, SB-M, SB-N, and SB-O because they were located on the crest of the Monarch HRDL berm. Geotechnical samples of the berm material, residuals, peat, and underlying sand were collected for water content, Atterberg limits, grain-size analysis (with hydrometer), unit weight, and UU strength. Direct shear (ASTM D3080) was evaluated at locations SB-L, SB-N, and SB-O. The UU strength testing was performed on the fine-grained residuals and peat samples; the direct shear testing was performed on the coarser grained berm and underlying sandy material. This testing was performed to obtain geotechnical data to evaluate the stability of the Monarch HRDL berm.

Field documentation for the 2002 and 2003 phases of the Geotechnical Investigation by BBL and MDEQ is included in Appendix A and Appendix MDEQ – A, respectively. The results of the Geotechnical Investigation are summarized in Section 3.2.4.4 of this document.

2.3 Sediment Investigation

Sediment data was collected to characterize the physical and chemical quality of sediments in Portage Creek, the Panelyte Marsh, the Former Monarch Raceway, and areas near selected groundwater seeps in the Former Bryant Mill Pond (after the USEPA Removal Action). Table 2-8 presents a summary of all the sediment samples submitted for chemical analysis during the various investigation phases over the period from 1993 – 2003, and Figure 10 shows the field location of the samples originally characterized as sediment by BBL. The results of physical characterization of sediments are discussed in Section 3.2.4.2 and Section 3.2.4.4. Section 4.3 presents the findings of chemical characterization of the sediment samples.

2.3.1 Clay Seam/East Bank Area

USEPA, MDEQ, and BBL collectively carried out four investigations of deposits referred to as the “Clay Seam” and the “East Bank” located along the east bank of Portage Creek, directly across from the Allied OU. Figure 5 shows the locations of these areas relative to the Allied OU, and Figure 6 presents a more detailed view, showing the locations of soil borings drilled in the areas.

During the 1998-1999 Removal Action at the Former Bryant Mill Pond, the USEPA collected several surface samples (three to six inches deep) of apparent clay from the Clay Seam area. These samples were analyzed for PCBs by the USEPA’s subcontracted laboratory, Western Michigan Environmental Services of Holland, Michigan. Based on the sample analytical results (one sample contained 1.1 mg/kg PCBs, all others were non-detect or less than 0.7 mg/kg PCBs), the USEPA decided not to excavate the Clay Seam area during the Removal Action (Weston, 2000).

After the Removal Action, the MDEQ expressed concern that the USEPA had not fully characterized the Clay Seam. The MDEQ informed MHLLC of its intentions to collect additional samples in the Clay Seam to further assess this area of the site. On August 25, 2000, BBL obtained split aliquots of MDEQ’s grab samples of residuals in the Clay Seam area, collected from the 0.5 to 1-feet and 2.5 to 3-feet intervals at the EB1 and EB2 locations using a hand auger (Figure 6). The sample locations and depths were selected by the MDEQ in the field as being representative of the exposed face of the Clay Seam along the bank of Portage Creek. BBL submitted the samples to KAR Laboratory in Kalamazoo, Michigan for PCB analysis.

At the MDEQ’s request, BBL conducted a investigation in April 2001 to delineate the vertical and horizontal extent of the Clay Seam area per a proposal (Cowin, 2000c) approved by the MDEQ (Bucholtz, 2001a). BBL advanced 45 boreholes (identified as locations EB3 through EB47 on Figure 6) on a 20-feet grid spacing to a maximum depth of 72 inches using a hand auger. BBL also collected three soil samples (BF1 through BF3) from the exposed face of the Clay Seam along the bank of Portage Creek. The MDEQ selected 8 samples of residuals from the 45 borings to be analyzed for PCBs. The selected samples of residuals were submitted to the project laboratory (Severn Trent Laboratories [STL]-Burlington - formerly known as Aquatec, Inc in Colchester, Vermont) for PCB analysis. The field notes from this sampling activity by BBL and MDEQ are in Appendix A and Appendix MDEQ – A, respectively. In August 2001, BBL collected four more samples (BF1-2 through BF4-2) to further characterize the PCB content of residuals that may be subject to erosion by the creek. These samples were collected from 6 to 12 inches deep in the Clay Seam along the east bank face of Portage Creek and submitted for PCB analysis in accordance with a proposal (Cowin, 2001a) that was modified in response to comments received from the MDEQ on August 7, 2001.

In July 2001, MDEQ requested an investigation of additional deposits of residuals observed in an area just upstream of the Clay Seam. BBL prepared a work plan (Cowin, 2001a and b) that was verbally approved by MDEQ (Bucholtz, 2001b) to determine the vertical and horizontal extent of these deposits, referred to as the East Bank area (Figure 6). In November 2001, 24 soil borings (identified on Figure 6 as EB48 through EB71) were drilled by hand auger to a maximum depth of 72 inches on a grid spacing of approximately 20 feet. Samples of soil and residuals selected by MDEQ were submitted to the project laboratory for PCB analysis.

The result of the investigations in the Clay Seam indicated the presence of relatively low concentrations of PCBs. As such, no further actions were taken and the data will be used in the FS to determine if additional actions are warranted in the future. Conversely, the results of the East Bank investigation indicated the presence of elevated levels of PCBs. The contamination in this area was delineated and excavated. Confirmation samples were collected and will be evaluated in the FS.

2.3.2 Groundwater Seep Sediment

Subsequent to completion of USEPA Removal Action at the Former Bryant Mill Pond, a number of groundwater seeps were observed at the Allied OU. The investigation of the seeps included sampling and analysis of groundwater (discussed in Section 2.4.9) as well as the sediment immediately beneath several of the seeps. In May 2000, the MDEQ conducted a preliminary assessment of the seep areas by collecting sediment for PCBs, in addition to, unfiltered groundwater water samples from seeps SP-A, SP-B, SP-C, SP-D, SP-E, SP-G, SP-H, SP-I, SP-J, SP-K, (formerly referred to as BMP Seep A, BMP Seep B, etc) and a sample from the ditch that flows from the Panelyte Marsh to Portage Creek. Based on the results of that preliminary assessment, BBL prepared a work plan (Cowin, 2000a and c) to conduct a more comprehensive investigation of seeps SP-A through SP-K as well as a number of other seeps identified after May 2000. In November 2002, based on a scope of work (Cowin, 2000a and c) approved with modifications by the MDEQ (Jordan, 2002), samples of sediment underlying seeps SP-N, SP-O, SP-82, SP-235, SP-242, SP-254, SP-299, SP-307, SP-508, and SP-611 were collected and submitted to the project laboratory for analysis of PCBs and total organic carbon (TOC). Samples of seep water were also collected for chemical analysis, as discussed in Section 2.4.9. The results of the chemical analyses associated with the investigations of the groundwater seep sediments are discussed in Section 4.3.1.1 and the seep locations are depicted on Figure 8.

2.4 Hydrogeological Investigation

The hydrogeological investigation activities, conducted in accordance with the *RI/FFS Work Plan* (BBEPC, 1993a) and subsequent plans and agreements (listed in Section 1.1), began at the Allied OU in 1993 and continued as of the preparation of this report. The hydrogeological conditions at the Allied OU have been assessed using the groundwater elevation and water quality data collected from 117 pre- and post-RI Work Plan monitoring and recovery wells, 40 observation wells and piezometers, and 20 groundwater seeps (177 unique locations). The locations of the wells, piezometers, and groundwater seeps are shown on Figure 8. Table 2-4 lists all the previously existing and newly installed wells and piezometers used for the Hydrogeological Investigation.

The information obtained and compiled to date during the hydrogeological investigation includes geologic descriptions, hydraulic conductivity data, geophysical logs, potentiometric surface elevations, and groundwater and leachate quality data. Methods used in the hydrogeological investigation and related activities from 1993 through 1998 are described in *Technical Memorandum 7* (BBL, 1997c) and *Addendum to Technical Memorandum 7* (BBL, 1999) and summarized in the following sections. The activities conducted for subsequent investigations are described in detail below.

2.4.1 Inventory of Pre-RI Monitoring Wells (1993)

In 1993, an inventory was conducted of existing (pre-RI) monitoring wells to identify those that could be used for the RI. The wells were inspected to assess surface seal integrity, depth to groundwater, depth of well, and apparent well condition in accordance with the *FSP* (BBEPC, 1993b). Of the fifty wells inspected, forty-seven were found to be serviceable for sampling and/or water level measurements. One well (MW-19B) was abandoned, and the two wells installed for pump tests (TW-1 and TW-2) were not appropriate for the purposes of the RI. The results of the inventory or pre-RI monitor wells are summarized in the list below. Table 2-5 presents the list of wells installed as of 2003 and their current situation.

1993 Inventory of Existing Wells

Well ID	Inspected	Rehabilitated	Abandoned	Water Levels	Sampled
MW-1	X			X	X
MW-2	X			X	X
MW-3	X			X	X
MW-4	X			X	
MW-5	X			X	X
MW-6	X			X	
MW-7	X	X		X	X
MW-8	X	X		X	X
MW-9	X			X	
MW-10	X			X	
MW-11	X			X	X
MW-12	X			X	X
MW-13	X			X	
MW-14	X			X	
MW-15	X	X		X	X
MW-16B	X	X		X	X
MW-16C	X	X		X	X
MW-17A	X	X		X	X
MW-17B	X	X		X	X
MW-18	X	X		X	X
MW-19B	X		X		
MW-19C	X	X		X	X
MW-19D	X	X		X	X
MW-20	X	X		X	X
MW-21	X	X		X	X
MW-22	X			X	
MW-23	X			X	X
MW-24	X			X	X
MW-25	X			X	X
MW-26	X			X	X
MW-30	X			X	
MW-101	X			X	
MW-102	X			X	
MW-103	X			X	
MW-104	X			X	X
MW-105	X			X	
MW-106	X			X	X
MW-107	X			X	
MW-108	X			X	X
MW-109	X			X	
MW-110	X			X	
MW-111	X			X	
MW-112	X			X	X
MW-113A	X			X	
MW-113B	X			X	
MW-114	X	X		X	X
MW-115	X			X	
MW-116	X			X	
TW-1	X				
TW-2	X				

2.4.2 Well and Piezometer Nomenclature

The existing (pre-RI) monitoring wells were given prefix designations of “MW-” plus a one, two, or three digit (100-series) number. In some cases, suffix letter designations were included in the well identification to indicate the hydrostratigraphic zone monitored: “A” indicates the surficial (water table) zone; “B” and “C” indicate intermediate and deep zones, respectively. Two pre-RI wells installed for pump tests were given designations of TW-1 and TW-2.

The above nomenclature for well identification was generally followed for the wells BBL installed for the RI from 1993 to 1999. Piezometers installed during this period were identified with a prefix of “P-” (e.g., piezometer P-1), and wells installed into water thought to be perched were given a suffix designation of "P" (e.g., MW-125P). The letter "R" was added as a suffix to well identification numbers to indicate a replacement well. For example, an intermediate-depth replacement well was given an identification number of MW-19BR.

In 2000, several observation wells (OW-series) were installed to obtain water level measurements in geologic media along the sheetpile wall. Several additional wells installed from 2000 to 2003 for groundwater characterization and long term monitoring were given 200-series identification numbers. The prefix "GWE" was given to wells constructed for groundwater extraction.

Temporary wells installed at the locations of groundwater seeps in 2002 were given a prefix designation of "SP."

2.4.3 Well and Piezometer Installation and Development

During the course of the RI, 90 monitoring and extraction wells and 40 piezometers and observation wells were installed in order to:

- Supplement the existing groundwater monitoring network with wells in and upgradient of the groundwater-surface water interface (GSI) zone;
- Provide long-term groundwater quality and water elevation monitoring capabilities;
- Replace several single-cased wells with double-cased wells where appropriate to maximize the potential for collecting representative groundwater samples;
- Control and monitor water levels behind the sheetpile wall;
- Replace wells damaged during Removal Action and IRM construction activities; and
- Characterize groundwater seep quality.

The wells and piezometers installed from 1993 to 2003 were constructed and developed in accordance with work plans produced for the various phases of investigation (BBEPC, 1993a, b, c; BBL, 1995a; Brown, 1998a;

Cowin, 2000a; McCune, 2000e; and Cowin, 2002b, c, d), as well as MDEQ input during field activities. The wells and piezometers (installed in native materials) were developed (via pumping, surging or similar techniques) to remove fine-grained materials and to improve the hydraulic connection with the surrounding formation, as appropriate. Table 2-5 presents the construction details for wells and piezometers installed for the RI. Copies of the field notes associated with the installation of wells and piezometers from 2000 to 2003 by BBL and MDEQ are provided in Appendix A and Appendix MDEQ – A, respectively. Field notes associated with installation of the other wells are provided in *Technical Memorandum 7* (BBL, 1997c) and *Addendum to Technical Memorandum 7* (BBL, 1999). Well construction details with geologic boring logs are provided for all RI wells in Appendix B. A detailed description of the methods for installing the monitoring wells between 2000 and 2003 is presented in Appendix C.

Although a general understanding was developed early on that PCBs were present in groundwater and leachate in certain areas of the OU, substantial uncertainty existed as to the conditions monitored by those wells and the quality of samples collected for PCB analysis. MHLLC and the MDEQ worked cooperatively through several phases of well installation, development, and sampling before creating a groundwater monitoring well network that yields a data set that satisfactorily defines site conditions (discussed in more detail in Section 4.4).

In order to gather groundwater data that would provide an accurate depiction of the nature and extent of PCBs at the site, wells were installed and developed in several rounds using different methods and materials to address the situation where artifacts of well construction (i.e., the intermixing of residuals and/or PCB-containing fill into the well annulus during installation) may have led to the collection of unrepresentative samples containing PCBs.

PCBs in a dissolved phase may move freely with leachate (liquid produced exclusively from residual material) and in groundwater. However, in order to be mobile, PCBs in a solid phase must comprise or be attached to particles that are small enough to travel through the interstices of the residuals and/or soil matrix. Colloid-sized particles, which range in size from 5 to 200 nanometers (Hem, 1985, citing Glasstone and Lewis, 1960), can be held in suspension and could conceivably be transported through the pore space of soil. A "perfect" monitoring well would yield groundwater samples that are free of particles that are retained in the soil matrix under natural flow conditions, and allow recovery of samples containing only representative fractions of chemicals that are dissolved and attached to mobile particles or colloids. In actuality, monitoring wells commonly become "silted" over time with particles introduced during well construction, formed or collected in the casing, or sheared from aquifer material near the well (Backhus, et al., 1993). Proper well installation, development, purging, and sampling serve to reduce sample turbidity and allow collection of groundwater samples that approach the *in situ* environment. Extraordinary measures have been taken during recent sampling efforts at the site to ensure groundwater samples are representative. Well construction and sampling techniques were modified to obtain a more representative ground water sample. The wells that were replaced are presented in Table 2-5 having a suffix letter designation "R". Given the vast amount of PCB impacted material at the site, it is generally understood that PCBs exist in the groundwater as well, as shown by the groundwater sampling results.

2.4.4 Monitoring Well Sampling

Groundwater and leachate samples were collected from monitoring wells (and from gas vent GV-10 in the partially constructed landfill cap on the Bryant FRDLs in 2002 and 2003) during each sampling event and analyzed in the field for temperature, specific conductance, pH, turbidity, and for some events oxidation-reduction potential (ORP) and dissolved oxygen (DO). After the field parameters stabilized, unfiltered groundwater samples were collected according to procedures described in the work plans and shipped to the project laboratory for analysis of one or more of the following parameters to characterize groundwater and leachate at the Allied OU[1]:

- TCL VOCs (USEPA CLP scope of work [SOW] for organics);
- TCL SVOCs (USEPA CLP SOW for organics);
- TCL pesticides and PCBs (USEPA CLP SOW for organics);
- TAL inorganic constituents (USEPA CLP SOW for inorganics);
- PCBs (USEPA SW-846 method 8081A, modified for PCBs only);
- Total suspended solids (USEPA method 160.2);
- Chemical oxygen demand (USEPA method 410.1);
- Conductance (USEPA method 120.1);

[1] Analytical methods for parameters have been modified since 1993. Current methods are listed.

- Total organic carbon (USEPA method 415.1);
- pH (USEPA method 150.1);
- Turbidity (USEPA method 180.1); and
- General water quality parameters:
  - Chloride (USEPA method 325.2)
  - Nitrate/nitrite nitrogen (USEPA method 353.2)
  - Sulfate (USEPA method 375.2)
  - Bicarbonate, carbonate, hydroxide, total alkalinity (USEPA method 310.1).

Table 2-6 presents a summary of the sample locations and chemical analyses performed on groundwater samples collected for the RI. Field documentation for groundwater sampling conducted from 2000 to 2003 is included in Appendix A. A detailed description of the groundwater sampling methods is provided in Appendix C. The results of chemical characterization of groundwater and leachate samples are discussed in Section 4.4.

2.4.5 Hydraulic Conductivity Measurements

In-situ measurements of hydraulic conductivity were obtained from several wells and piezometers installed at the site. Wells installed in 1993 were subjected to rising head tests using a solid PVC slug and/or a pneumatic rising pressure system that lowered static water levels under positive air pressure to obtain very local hydraulic conductivity values. The pneumatic rising head tests were performed only on wells screened in highly conductive formations. The rising head data were analyzed using the Bouwer-Rice (1976) method. The field and analytical methods for determining hydraulic conductivities in single wells are described in further detail in *Technical Memorandum 7* (BBL, 1997c).

Additional in-situ measurements of hydraulic conductivity were taken in 2000 using pump-test data obtained at the GWE-1A and GWE-4A groundwater extraction well locations. These data were analyzed using the Walton (1962) specific capacity test method. Ex-situ estimates of hydraulic conductivity were calculated by evaluating the results of consolidation analyses and using standard soil mechanics equations. Empirical estimates of hydraulic conductivity also were made from particle size data using the Beyer Method (Vukovic and Soro, 1992). The locations and methods for determining hydraulic conductivities are summarized in the table below.

Hydraulic Conductivity Methods by Location

Well/Boring Location	Bouwer-Rice Method	Walton Specific Capacity Method	Lambe and Whitman Calculation	Beyer Method
MW-12R	X			
MW-123A	X			
GWE-1A		X		
MW-122A	X			
MW-22A	X			
MW-2S	X			
P-1	X			
P-2	X			
P-3	X			
MW-120A	X			
F5-1			X	
F5-3			X	
H1-2			X	
H1-4			X	
H3-2			X	
H3-5			X	
H6-2			X	
H6-3			X	
MW-125B	X			
MW-8A	X			
MW-125A	X			
MW-126A	X			
MW-128A	X			
MW-20B	X			
GWE-4				X
GWE-4A				X
GWE-5				X
MW-121A	X			
MW-127A	X			
GWE-4A		X		
MW-126B	X			
GWE-3				X
MW-124A	X			
MW-19BR	X			
GWE-4				X

The methods of evaluating hydraulic conductivity are presented in Appendix D. The results of these evaluations are discussed in Section 3.2.5.3.

2.4.6 Water Level Measurements

A variety of water-level monitoring activities have been carried out at the Allied OU over the past 13 years. Between 1993 and 1999, periodic measurements were taken at selected wells primarily to support the groundwater sampling events (Table 3-4A). Beginning in January 2000, water-level data were collected more frequently at selected wells, piezometers, and staff gauges to assess the performance of the groundwater recovery component of the IRM (Table 3-4B). BBL conducted weekly water-level monitoring from January 7, 2000 through December 21, 2000 (Table 3-4B). In addition, water-level measurements were collected to evaluate seasonal effects (from January 2001 through September 2006 as presented in Table 3-4C), the presence of water in gas vents (from October 2001 through May 2003 as presented in Table 3-5), and elevations in seep wells (from January to June 2003 as shown in Table 3-6). LTI-Limno Tech continued the weekly monitoring until July 3, 2001 (Table 3-4C). Generally, LTI-Limno Tech changed to collecting water level data to a monthly frequency from July 2001 to September 2006 as presented in Table 3-4C. The results of these activities are discussed in Section 3.2.5.4.

2.4.7 Gamma Ray Logging

Natural gamma radiation measurements can be used to assess the presence of clay-containing units, which generally emit greater amounts of natural radiation, and aid in the correlation of these subsurface units between wells. Gamma ray logging was conducted at 13 wells in 1993, but the results were inconclusive and were not used in the development of the physical characterization presented in Section 3. The available information is reported in *Technical Memorandum 7* (BBL, 1997c).

2.4.8 Well Decommissioning Activities

Of the 180 existing and newly installed monitoring wells, observation wells, and piezometers used for the RI (as well as the three pre-RI wells that were not used in the RI), 69 were decommissioned during five different events. These wells and piezometers were selected for decommissioning because they obstructed planned activities, were no longer useful, or had been damaged during site construction activities. The five decommissioning events were completed at the Allied OU as follows:

- One well was decommissioned in 1993 due to concerns of a hydraulic connection between the screened interval and a lower saturated zone;

- Twenty-one monitoring wells were decommissioned in October 1998 to facilitate the USEPA's Removal Action at the Former Bryant Mill Pond;

- Thirty-seven monitoring wells and piezometers determined to be unnecessary for monitoring at the Allied OU were decommissioned between November 1999 and March 2000 (Bradley, 1999);

- Seven monitoring wells, observation wells, and piezometers were decommissioned between April and October 2000 because they were damaged during construction activities associated with the IRM; and

- Three additional monitoring wells damaged during IRM construction activities were decommissioned during June and July 2002.

The most common abandonment method was by over-drilling the well with hollow-stem augers, followed by removing the well materials (to the extent possible) and injecting a cement-bentonite mixture into the borehole through a tremie pipe. A detailed description of the procedures used for decommissioning wells and piezometers at the Allied OU are described in Appendix C and summarized in Table 2-5.

2.4.9 Groundwater Seeps Investigation

Groundwater seeps have long been a feature at the OU and are typical of such regional groundwater discharge zones as Portage Creek. A spring (commonly referred to within this RI as a groundwater seep) is a feature that exists when groundwater is under sufficient hydrostatic pressure enough to rise above the aquifer containing it. Although it has not been measured, the groundwater velocities associated with the seeps at the point of discharge are significantly greater than those of typical groundwater. The sizes of the particles suspended/transported in the discharge of the seeps are significantly greater than those of typical groundwater. Normal groundwater velocities and the pore spaces of typical drift aquifers limit the size of transported particles. The velocities and the mass of particulate material transported in association with these features can be observed. This process is expected to result in subsurface erosion typical of springs that serve to develop a more efficient transport path for particulates to the surface. Surface flow and erosion which carries particulates (i.e., soils/sediments) toward and into Portage Creek can also be observed. The particulates transported in the subsurface and surface by the springs/seeps will include those associated with the PCB contaminant.

Prior to the RI, PCBs were periodically detected in water samples collected from groundwater seeps identified as Seep 1 and Seep 2 (also known as Seep 26). The analytical results of these sampling events are summarized in Figure 15A of the *DCS* (BBEPC, 1992). Seep 2/Seep 26 was identified as Rivulet 2 during RI sampling activities conducted in 1993 (BBL, 1997c), and as SP-299 during sampling events in 2002 and 2003 and are depicted in Figure 8.

After the USEPA completed the Removal Action at the Former Bryant Mill Pond, a number of existing groundwater seeps became apparent along the perimeter of the backfilled area north of the Type III Landfill and east of the Panelyte Property as shown in Figure 8. On May 23, 2000 the MDEQ conducted a preliminary assessment and collected unfiltered water samples from seeps SP-A, SP-B, SP-C, SP-D, SP-E, SP-G, SP-H, SP-I, SP-J, and SP-K, and a sample of surface water from a ditch identified as SP-F. MDEQ provided BBL with a split aliquot of the water samples collected from each seep location. BBL submitted the samples to the project laboratory for analysis of PCB, total suspended solids (TSS), and nine metals (arsenic, barium, cadmium, chromium, copper, lead, selenium, silver, and zinc). Based on the results of that preliminary assessment, BBL prepared a work plan (Cowin, 2000a and c) to conduct a more comprehensive investigation of seeps SP-A through SP-K as well as a number of other seeps identified after May 2000. This work was approved with modifications by the MDEQ on November 21, 2002 (Jordan, 2002).

Beginning in December 2002, a more comprehensive investigation of the groundwater seeps was conducted in general accordance with a groundwater seep investigation work plan (Cowin, 2002a and c). The MDEQ provided conditional approval of the work plan, requiring BBL to sample the soils underlying selected seeps, install temporary wells to sample the seeps, and analyze all water samples for TAL parameters, in addition to PCBs and TSS. A summary of groundwater seep samples collected for the RI is presented in Table 2-7.

Temporary wells were installed at 20 seep locations in November 2002. These locations are: SP-A, SP-B, SP-D, SP-E, SP-G, SP-H, SP-I, SP-J, and SP-K, and additional seeps identified as SP-M, SP-N, SP-O, SP-82, SP-235, SP-242, SP-254, SP-299, SP-307, SP-508, and SP-611 (see Figure 8). Each seep was excavated 3 to 4 feet deep and 2 to 6 feet wide and backfilled with clean sand, then a shallow well was placed into the clean backfill. As noted in Section 2.3.2, soils underlying the wells at some of these locations were also sampled during this event. The temporary seep wells were constructed of an approximately 4.5-feet long, 2-inch outer diameter Schedule 40 PVC with a 0.75-feet screen and 0.010-inch slots. A non-woven geotextile was slit and placed over the well head and covered with pea gravel to stabilize the fill and minimize the introduction of particulates from the ground surface into the well. Figure 9 presents a schematic of the temporary well installed at each seep location.

The temporary wells were sampled during December 2002. While purging the temporary wells, samples of the seep water were analyzed in the field for temperature, specific conductance, pH, turbidity, ORP, and DO. After the field parameters stabilized, unfiltered samples of the seep water were collected and shipped to the project laboratory for analysis of the following parameters:

- PCBs (USEPA SW-846 method 8081A, modified for PCBs only);
- TAL inorganic constituents (USEPA CLP SOW for inorganics); and
- TSS (USEPA method 160.2).

Based on observations of an oily sheen at seeps SP-G, SP-H, SP-I, and SP-J, water samples from these locations were also analyzed for TCL VOCs and TCL SVOCs (USEPA CLP SOW for organics) during the December 2002 sampling event.

- In April and May 2003, additional water samples were collected from the temporary wells at 14 of the groundwater seeps. Water samples were collected from seeps SP-B, SP-H, SP-J, SP-K, SP-N, SP-O, SP-82, SP-235, SP-242, SP-254, SP-299, SP-307, SP-508, and SP-611 and submitted to the project laboratory for analysis of PCBs, TAL constituents, and TSS according to the methods listed above, as well as the following general water quality parameters:

  a. Bicarbonate, carbonate, hydroxide, total alkalinity (USEPA Method 310.1);
  b. Chloride (USEPA Method 352.2);
  c. Nitrate/nitrite nitrogen (USEPA Method 353.2); and
  d. Sulfate (USEPA Method 375.2).

Additional details regarding the groundwater seeps investigation are provided in Appendix C. The results of chemical characterization of the groundwater seeps are discussed in Section 4.4.2.

2.4.10 Other Groundwater Investigations

During the course of this RI, other groundwater sampling activities were conducted. These other sampling activities were conducted in 2002 and 2003 after the construction of the sheetpiling and involved collecting groundwater samples from both permanent and temporary sumps (2002) and leaking sheetpile joints (2003). Groundwater samples were collected from five permanent sumps (PS1 to PS5), four temporary sumps (TS7 through TS10), and three sheetpile locations (SP57, SP380, and SP406-407). The groundwater samples were collected from the permanent sumps by allowing the sump pump to lower the groundwater table below the inlets of the French drains. The sheetpile water samples were collected directly from the leaking area. A summary of groundwater seep samples collected for the RI is presented in Table 2-11. Figure 3 presents the location of the sumps that were sampled. The results of chemical characterization of the groundwater seeps are discussed in Section 4.4.2.

2.5 Surface Water Investigations

A variety of surface water samples have been collected from Portage Creek to assess water quality conditions. A summary of surface water samples collected for the RI is presented in Table 2-9. The surface water sampling locations are shown on Figure 11. The surface water investigations conducted at the site are discussed below and the results are discussed in later sections of this report.

The 1993-1997 investigations included the collection of surface water samples and flow measurements in Portage Creek to characterize PCB concentrations across a wide range of flow conditions. Details of the 1993 – 1997 investigation methods are presented in Section 2.1 of *Technical Memorandum 11* (BBL, 2000a).

The sampling conducted in 1998-1999 was not for site characterization purposes, but was designed primarily to assess the impacts of the USEPA Removal Action at the Former Bryant Mill Pond. Therefore, the methods and findings of this sampling event are presented in Appendix E.

The MDEQ Remediation and Redevelopment Division (RRD) initiated a LTM Program in 1999 for Portage Creek and the Kalamazoo River. As part of this ongoing program, surface water samples were collected from eight sampling stations on Portage Creek located upstream and downstream of the Allied OU. The collected surface water samples were generally analyzed for PCBs and TSS. The results have been published in three reports prepared by the MDEQ (CDM, 2001a, 2002b, and 2002c).

On May 14, 2003 one surface water sample was collected from Portage Creek at the downstream end of the sheetpile and submitted to the project laboratory for analysis of CLP TAL and general water quality parameters. The analytical results of this sample are compared to groundwater analytical data collected from wells along a flow path from these disposal areas to Portage Creek in Section 5.3.2. The MDEQ-approved sampling (Bucholtz, 2003b) was designed as described in a memorandum (Cowin, 2003) that summarized the proposed 2003 groundwater and surface water sampling program.

2.6 Biota Investigation

A biota investigation was conducted in 1993 to assess the concentrations of PCBs and other regulated constituents in fish throughout the Kalamazoo River Superfund Site, including the Allied OU. The sampling effort at the Allied OU involved collecting and analyzing resident common carp, and white suckers from the Former Bryant Mill Pond section of Portage Creek in accordance with the MDEQ-approved *RI/FFS Work Plan* (BBEPC, 1993a) and the *Biota Sampling Plan* (CDM, 1993). The fish were collected from the area of Portage Creek north of the FRDLs and south of Alcott Street, as shown on Figure 11. A summary of fish samples collected at the Allied OU for the RI is presented in Table 2-10.

Carp were selected as a target species for sampling because they are one of the most abundant and widespread fish in the Kalamazoo River drainage basin, making them a good indicator species for trend analysis. White suckers were identified as a target species representing a forage fish available for consumption by piscivorous predators. A mark and recapture sampling technique was used to collect eleven specimens of each species. To facilitate comparison of the fish data to the MDCH fish consumption advisories, the fish retained for PCB analysis were targeted among specific size classes for each species. Six carp from 18 to 22 inches in length, five carp greater than 23 inches in length, and white suckers from 6 to 12 inches in length were targeted for collection. Prior to shipment to the laboratory for analysis, each fish was weighed and measured to determine live weight and length. All fish also were examined for the presence of external abnormalities.

Carp were processed at the laboratory for analysis as skin-off fillet (11 samples) and remaining-carcass samples (6 samples). The carp samples were analyzed for PCBs, pesticides, total mercury, and percent lipids. White suckers (11 samples) were analyzed as discrete whole-body samples for PCBs, pesticides, total mercury, and percent lipids.

Additional details of the 1993 biota investigation activities at the Allied OU are presented in Section 2.2 of *Technical Memorandum 11* (BBL, 2000a), and the results are discussed in Section 4.6 of this report. The findings of the biota investigation for other areas of the Kalamazoo River Superfund Site are discussed in *Technical Memorandum 14 – Biota Investigation* (MDEQ, 2002).

Fish sampling activities were conducted at the Allied OU in 1998-1999, not for the site characterization purposes of the RI, but to monitor fish PCB concentrations before, during, and after completion of the USEPA

Removal Action at the Former Bryant Mill Pond. Channel catfish and white suckers were the species selected to monitor and assess the impacts of the Removal Action. Samples of caged channel catfish and whole-body white sucker were analyzed for PCBs and percent lipids. The methods and findings of the Removal Action fish monitoring (i.e., the efforts conducted before and during the action) are discussed in Appendix E.

The MDEQ RRD initiated a LTM Program in 1999 for the Kalamazoo River and Portage Creek. Resident adult carp (fillets) and yearling carp (whole-body), adult and yearling white suckers (whole-body), and/or caged yearling channel catfish (whole-body) are collected from several locations along Portage Creek, including the Former Bryant Mill Pond, on a periodic basis and analyzed for PCBs (by Aroclor or Congener) and percent lipids. The results have been published in three reports prepared by the MDEQ (CDM, 2001a, 2002b, and 2002c). Additional fish were collected under the LTM Program in 2006 and included fish from Portage Creek. These data are not yet available and the results have yet to be published. A summary of the fish samples applicable to this RI that were collected under the LTM program at the Allied OU are presented in Table 2-10.The fish at the Allied OU were collected in Portage Creek from the southeast corner of the FRDLs to south of Alcott Street, as shown on Figure 11.

2.7 Wetlands Assessment

The wetlands assessment at the Allied OU was conducted to characterize wetland areas with respect to the presence of hydrophilic vegetation, hydric soils, and wetland hydrologic features according to the criteria outlined in the *RI/FFS Work Plan* (BBEPC, 1993a). The assessment was undertaken to determine whether areas at the site that appeared to be supporting wetland vegetation could be defined as wetlands following USACE guidance (1987). The wetlands assessment activities included the review of both the U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) Map (USFWS, 1981) and the United States Geological Survey (USGS) topographic map for the Kalamazoo Quadrangle (USGS, 1973) followed by field investigation/verification.

2.7.1 1993 Wetlands Assessment

BBL conducted a field investigation on October 7, 1993 to verify existing information regarding wetlands at the OU. Five locations were assessed for standard wetland indicator parameters of vegetation, hydrology, and soils according to the USACE *Wetlands Delineation Manual* (USACE, 1987). The wetlands assessment methodology was based on visual observations of the indicator parameters and an understanding of historical land use. Vegetation was evaluated by noting which dominant wetland plant indicator species were present, and the approximate percent of wetland area covered by these species. Hydrology was evaluated by observing the degree of soil saturation, and noting field evidence of surface inundation. Soils were evaluated to a depth of 20 inches by noting hydric soil characteristics, mottling, gleying, color, and whether the soil was a histosol. Further details of the wetlands assessment are presented in Section 2.3 of *Technical Memorandum 11* (BBL, 2000a). The findings of the wetland assessment are discussed in Section 3.3.1.

2.7.2 MDEQ 2001 Wetlands Delineation

In 2001, MDEQ conducted a wetland delineation study to more definitively determine the boundaries of wetland areas shown on NWI maps for areas of the Kalamazoo River Superfund Site, including the Allied OU, to support risk management and remedial decision-making efforts. The MDEQ used three primary criteria to identify wetlands: hydrology, soils, and the vegetation. The report prepared for MDEQ included a review of existing data (e.g. NWI maps, soils maps, topographic maps, and flow and hydrological information), conducting field surveys to confirm wetland boundaries, and presentation of the information on modified aerial maps. Detailed information regarding the wetland delineation methodology is presented in Section 2 of the *Kalamazoo River and Portage Creek Wetland Delineation Study* (CDM, 2002a). The results of the MDEQ Wetland Delineation are discussed in Section 3.3.2.

2.8 QA/QC Review of Data

Analytical data reports for the Allied OU RI samples were subjected to detailed review and evaluation to assess overall analytical precision and accuracy. Analytical data, organized into sample delivery groups, were reviewed using techniques appropriate to the various media and constituents tested.

Results of the data quality review for samples collected during the early RI investigations are presented in the QA/QC summary and data review reports in Appendix H of *Technical Memorandum 4* (BBL, 1994a), Appendices C and D of *Technical Memorandum 7* (BBL, 1997c), Appendices D and E of the *Addendum to Technical Memorandum 7* (BBL, 1999), and Appendices E and F of *Technical Memorandum 11* (BBL, 2000a). QA/QC reviews and data review reports for RI analytical data obtained during more recent site investigations are presented in Appendices J through N and R, respectively, of this report. The data review procedures complied with applicable USEPA guidance (USEPA, 1989a; 1991a; 1991b; 1991c; and 1991d) and the *QAPP* (BBEPC, 1993c). Analytical precision and accuracy were also evaluated according to USEPA guidance

(USEPA, 1989a). QA/QC data qualifiers and their specific interpretations are described in the technical memoranda as well as the appropriate tables and text of this report.

Field and analytical data collected by MDEQ were subject to QA/QC procedures as outlined in Section 4 and Section 5 of the *LTM Sampling Plan* for 2001 (CDM, 2001b). Field quality control samples were collected to evaluate precision and accuracy. In addition, the project's Quality Assurance Officer (QAO) followed procedures to ensure the integrity of data received from MDEQ's laboratory Northeast Analytical Laboratory (NEA). The QAO responsibilities were, but not limited to, checking data package for completeness, traceability of samples, holding times, instrument calibration documentation, lab control standards, spike recoveries, et cetera. Based on the information from the data evaluation, the QAO may add qualifiers to the data. The project specific quality assurance objectives are described in Section 4.4 of the *LTM Sampling Plan* (CDM, 1999) and Section 4.4 of the *LTM Sampling Plan* (CDM, 2001b). Additional information can be obtained in Section 2.5 of the 1999, 2000, and 2001 LTM sampling reports (CDM, 2001a, 2002b, and 2002c).

3. Physical Characterization

3.1 Regional Information

The following subsections present pertinent information on the regional characteristics of the site, including climate, topography and drainage, geology and hydrogeology, wetlands, and groundwater.

3.1.1 Climate

The City of Kalamazoo is located approximately 35 miles east of Lake Michigan and 35 miles north of the Indiana border in what is termed the Southwest Lower Climatic Division. There is a pronounced lake effect on the climate of Kalamazoo throughout most of the year due to the prevailing westerly winds and the close proximity to Lake Michigan. The lake effect results in a greater incidence of cloudiness and snowfall in fall and winter, and moderates the temperature year-round. Climatological data for the period of 1951 – 1980 from the National Weather Service Office in Grand Rapids, Michigan located approximately 50 miles to the north, indicate the prevailing wind direction to be southwesterly, averaging 10 miles per hour. The average percent possible sunshine ranges from 21 percent in December to 64 percent in July, averaging approximately 46 percent annually. The average daily temperature ranges from a minimum of 16.5 degrees Fahrenheit (ºF) in January to a maximum of 84.9 ºF in August, with a mean annual average of 49.7 ºF. The average date of the last freezing temperature is May 1, and the average date of the first freezing temperature is October 13. The average annual precipitation is 34.8 inches, of which 59 percent (20.5 inches) occurs between April and September. The average annual snowfall is 73.6 inches, with an average of 71 days per season with 1 or more inches of snow on the ground (Michigan State University [MSU], 2003).

3.1.2 Regional Topography and Drainage

The Kalamazoo River watershed is located in the southwestern portion of Michigan's lower peninsula (Figure 1). The watershed contains approximately 400 miles of stream tributaries and encompasses a drainage area of over 2,000 square miles. The river rises near Jackson, Michigan and flows northwesterly for approximately 123 miles before draining into Lake Michigan near the town of Saugatuck (BBL, 2000b). The base flow in this watershed is the result of a groundwater fed drainage system typical of the glacial deposits and landforms in this area.

The Kalamazoo area is located within a region with landforms characterized by hilly end moraines, from 10 to 25 miles apart, which dominate much of the lower part of Michigan (Schaetzl, 2003). Landforms in the region have been impacted by human activities, including the construction of dams and dikes within and along the Kalamazoo River and its tributaries. Between Morrow Lake and the mouth of the river at Saugatuck, the Kalamazoo River is an alternating series of free-flowing sections and impoundments formed by low-level dams. There are eight dams in this stretch of the river – several have been permanently opened and are no longer maintained, although they still impound some water and sediment. The stretch of Portage Creek that has been the focus of the investigations carried out in support of this RI Report and the RI for the Kalamazoo River Superfund Site is the 2.5 miles from Cork Street downstream to the confluence with the Kalamazoo River. Significant portions of Portage Creek in this reach have been channelized to reduce flooding potential since the creek flows through industrial, residential, commercial, and recreational areas. Near the OU, the Alcott Street Dam formerly impounded water to form the Bryant Mill Pond. As discussed in Section 1.2.1, the dam gates were opened in the mid-1970s and the water level dropped approximately 13 feet. The remains of the dam continue to impound some water and sediment in Portage Creek. Approximately 0.3 miles upstream of the OU on Portage Creek (south of Cork Street and beyond the MHLLC property boundary) is the Monarch Mill Pond, formed by a dam with an approximately 30-feet drop (www.kalamazooriver.net, 2003). In addition to the impacts of the various dams, low areas along the Kalamazoo River and its tributaries have been filled with excavated soils and man-made materials.

Hydrologic information for Portage Creek was obtained from two USGS gage stations. Data were continuously collected between 1964 and 1992 at the Lovers Lane gage station (USGS Gage No. 04106300), located upstream of the site approximately 0.9 miles south of Cork Street. From 1975 to 1986, data were also continuously collected at the Reed Street gage station (USGS Gage No. 04106500), which was located approximately 0.3 miles north of Alcott Street, downstream of the site. As is typical in northern temperate climates, the highest average daily flows occur in the spring as a result of snowmelt, spring precipitation, and higher runoff rates, while the lowest flows occur in late summer and early fall when water losses to soil infiltration and evapotranspiration are greatest. The highest daily average flows at Portage Creek occur in March and April, and lowest flows generally occur in September (BBL, 2000b). Groundwater fed drainage systems predominate in the glacial sediments in this section of the state. Portage Creek is a groundwater fed gaining system as is demonstrated by hydraulic heads above the elevation of surface water in wells adjacent to the creek, and the presence of groundwater springs and seeps that discharge over land directly into Portage Creek.

3.1.3 Regional Geology

3.1.3.1 Bedrock

The bedrock underlying the region near the Allied OU consists of the Coldwater Shale formation. This formation is primarily fossiliferous shale (which contains limestone in some areas) and was deposited as mud in an offshore marine environment during early Mississippian time, about 350 million years ago (Dorr and Eschman, 1996). The surface of the formation, which near the site is estimated at an elevation of 650 to 700 feet above mean sea level (AMSL) (Monahan et al., 1983), slopes downward to the southwest. The formation is greater than 500 feet thick, with bedding dipping toward the northeast (Rheaume, 1990). Based on the elevation range provided above, the depth to bedrock beneath the site is estimated to be between 100 and 150 feet.

3.1.3.2 Overburden

The last Wisconsinan glacier retreated from the region about 15,000 to 17,000 years ago, resulting in a somewhat complex mixture of outwash and till layers deposited above the bedrock (Kehew et al., 1999). As the ice front made its final retreat to the north, a broad plain of outwash sand and gravel was deposited by meltwater draining to the south. As the ice moved further northward, a topographic low point allowed the meltwater to drain to the north. This flow reversal resulted in downcutting of the outwash plain and formation of the present down-cut drainage channels of the Kalamazoo River Valley. Once the ice sheet retreated out of Kalamazoo County, new drainage patterns were created directing meltwater away from the Kalamazoo River Valley. As the new drainage patterns evolved, the flow through the Kalamazoo River decreased to its present pattern (Rheaume, 1990).

Post-glacial soils in the region that can be classified fall primarily into the Oshtemo-Kalamazoo-Glendora complex. Portions of the region are urbanized and therefore the identification of the soils is not possible. The map units (as described in U.S. Department of Agriculture [USDA], 1979) range from nearly level areas of very poorly drained Glendora soil along Portage Creek to rolling, well-drained areas of Kalamazoo soil and hilly, well-drained deposits of Oshtemo soil on the upland areas. The surface layer is generally dark sandy loam (about 8 to 11 inches thick) and the subsurface (44 to 60 inches thick) ranges from sand, loamy sand, clay loam, gravelly sand, and sandy loam. Small pockets of poorly drained Sleeth soils are present in depressions and small areas of excessively drained Coloma and Plainfield soils also occur. Permeability is moderate to rapid, runoff is slow to rapid, and available water capacity is low to moderate (USDA, 1979).

3.1.4 Regional Hydrogeology

Groundwater in the region results mainly from infiltration of precipitation (rainfall and snow melt). Three percent of Kalamazoo County is covered by marshes and wetlands that recharge the groundwater system (Rheaume, 1990). The groundwater recharge rate in Kalamazoo County is generally greatest between November and May, with an average groundwater recharge rate in the Kalamazoo River basin of nine inches per year[1] (Allen et al., 1973). Extensive and highly prolific aquifers occur in the outwash deposits that supply the base flow for the Kalamazoo River watershed. These prolific aquifers and permeable soils have also played a part in the development of the water shed and the dominantly groundwater fed characteristics of the Kalamazoo River and tributaries in this regional drainage basin.

Groundwater is the primary water source in the City of Kalamazoo. In this region, groundwater supplies are withdrawn primarily from the more permeable zones of the unconsolidated soils that overlie the bedrock. Allen et al. (1973) identified four saturated soil units in the region: an upper sand and gravel aquifer; an intervening aquiclude with low permeability consisting of fine material (i.e., silt and clay); a lower sand and gravel aquifer; and a lower aquiclude above the bedrock. The upper and lower outwash sand and gravel deposits serve as the source of groundwater for most domestic wells and all public supply wells in the region. It is estimated that the unconsolidated groundwater aquifers of Kalamazoo County can support sustained groundwater withdrawals of 147 million gallons per day. The few wells completed in the Coldwater Shale produce low yields of highly mineralized groundwater (Rheaume, 1990). A municipal well field located at 215 Stockbridge Avenue, approximately 0.5 mile north of the Allied OU and adjacent to Portage Creek, produces the largest component of water supply to Kalamazoo (Paquin, 1999).

The regional groundwater flow direction is northward towards the Kalamazoo River, which acts as the principal hydrologic boundary and discharge area for groundwater in the county (Rheaume, 1990). Shallow groundwater flow systems in the area (such as that near the Allied OU) drain to Kalamazoo River tributaries, including Portage Creek. This is supported by data collected from groundwater monitoring wells at OU1.

3.2 Site-Specific Information

Extensive investigations have been conducted at the Allied OU in support of the RI. The following sections detail the findings of these investigations conducted to characterize the physical conditions of the site. The results of chemical characterization of site media are presented in Section 4.

3.2.1 Site Meteorology

As discussed in Section 2.1, meteorological information was collected from an on-site weather station as part of the 1993 Air Investigation at the Allied OU. These data were used in conjunction with PCB analytical data (discussed in Section 4.1) to assess the potential for risk to human health and the environment from air emissions at the Allied OU. Meteorological data collected during the monitoring period (June 6 to August 29, 1993) at the Allied OU weather station are presented in Table 3-1. A summary of meteorological information is presented below.

Allied Paper, Inc. Operable Unit
Summary of Meteorological Measurements

Parameter	Recorded Value
Vector mean wind direction	South-southeast
Range of 24-hour average wind speeds	2.3 - 7.7 miles per hour
Peak (one-hour average) wind speed	11.5 miles per hour
Range of 24-hour average temperatures	58.4 - 76.6 °F
Lowest/highest recorded one-hour temperature	44.2 °F/89.3 °F
Range of 24-hour average solar radiation	0.056 - 0.48 Langleys
Range of 24-hour average relative humidity	56 - 79 percent

Period of study: June 6 to August 29, 1993 (15 weeks).
Frequency of data collection: one day per week.

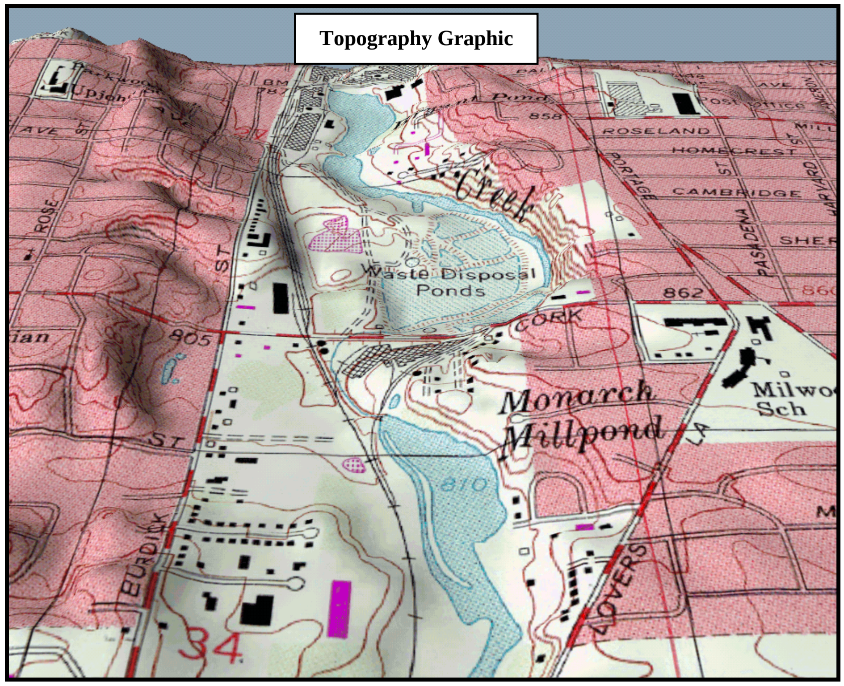
Detailed results of the OU-specific meteorological monitoring and air sampling as well as an assessment of risks associated with PCBs in air at the site are presented in Sections 3 and 4, respectively, of *Technical Memorandum 4* (BBL, 1994a). Chemical data compiled during the Air Investigation are discussed in Section 4.1. Historical information regarding local meteorological trends for Kalamazoo and Allegan counties between 1951 and 1980 is presented in Section 2.3 of the *DCS* (BBEPC, 1992) and Section 2.1 of the *RI/FFS Work Plan* (BBEPC, 1993a).

3.2.2 Site Topography and Drainage

The Allied OU is situated on the floor of a north-south trending valley drained by Portage Creek (USGS, 1995). The creek flows northward, emptying into the Kalamazoo River about 2.25 miles north of the site. As shown below, the valley is flanked by hills formed of unconsolidated material that rise about 80 feet above creek level to the east and 100 feet above creek level to the west. The graphic/map shown below and Figure 12 depict the general topography of the Allied OU and its environs. Total relief across the site is about 70 feet, with

[1] Average calculated between 1933 and 1964.

elevations ranging from about 783 feet AMSL at the downstream end of Portage Creek (near the Alcott Street Dam) to about 853 feet AMSL at the highest point of the Monarch HRDL. The land surface of the Allied OU generally slopes toward Portage Creek.



The aerial photographs, some of the land survey data, and other information used to develop both the graphic shown to the right and the topography depicted on Figure 12 pre-date several activities that modified the topography of the site. These activities include the USEPA Removal Action and the IRM, as discussed in Sections 1.2.3.1 and 1.2.3.2, respectively. The IRM is described in further detail in Appendix F. Filling and re-grading activities associated with the IRM have resulted in topographic modifications, particularly in the Bryant HRDL and FRDLs area. Although the IRM is now complete, it was in progress at the time the data were collected to generate Figure 12; therefore, final topographic information for the site is not available at this time (the data incorporated into Figure 12 was collected in 1991, 1999, 2002, and 2003).

Surface runoff at the Allied OU is generally directed to Portage Creek. Runoff from the area capped during the IRM (i.e., the Bryant HRDL and FRDLs) is currently managed through a series of engineered drainage ditches and swales, routed to a settling basin (at the location of FRDL #2), and discharged to Portage Creek through an engineered outlet. During construction of the IRM, runoff from this area was collected at the settling basin, treated on site, and discharged to the City of Kalamazoo wastewater treatment plant. Overland flow in other areas of the site is routed directly to Portage Creek or to drainage channels and low-lying areas that, in turn, run to the creek. These drainage channels are shown on Figure 12. As seen on this figure, overland flow from the northern end of the Western Disposal area drains toward the Panelyte Marsh; water from this marsh flows through a culvert beneath an access road and then into the creek. Similarly, overland flow at the southern end of the Western Disposal Area runs through ditches to a low-lying area immediately adjacent to Cork Street, into a culvert beneath the access road, and into the creek.

At the Monarch HRDL, the dike that parallels the creek forms a slight lip that directs runoff to the east and west ends of the HRDL before draining to the creek. Immediately west of the Monarch HRDL, a 13-feet diameter culvert for a former mill race channel crosses beneath Cork Street and empties into Portage Creek approximately 100 feet west of the Monarch Clarifier (Figure 12). A concrete bulkhead forms a wall at the upstream end of the culvert, which terminates approximately 10 feet south of Cork Street. The culvert currently receives water from stormwater catch basins along Cork Street.

Surface runoff from other study areas is also directed to Portage Creek between Cork and Alcott Streets. Several storm water outfalls, intermittent streams, drainage swales, and/or overland flow discharge points are located along the creek on properties owned by the City of Kalamazoo, private residents, the Golden Age retirement home, and Stryker Corporation. At least three storm sewer lines are located on the Panelyte Property. Although the exact number and orientation of these storm sewers were not researched for the Allied OU RI, observations indicate that they discharge into the Former Bryant Mill Pond area en route to Portage Creek.

3.2.3 Site Hydrology

Prior to field work in support of the surface water investigations discussed in Section 2.5, flow rates for Portage Creek at the Allied OU were estimated by analyzing available data from the Reed Street (June 1975 – September 1986) and the Lovers Lane (October 1964 – September 1992) gage stations. These data were used to estimate both high-flow (corresponding to the 10 percent exceedance flow) and baseflow (corresponding to the 80 percent exceedance flow) conditions at Alcott Street. The threshold for high-flow conditions was estimated to be approximately 75 cubic feet per second (cfs), and the threshold for baseflow conditions was estimated to be 40 cfs.

Measurements of surface water levels and velocity were used to calculate flow rates in Portage Creek at the Cork Street and Alcott Street sampling locations during each of the surface water sampling events discussed in Section 2.5 (see Figure 13A and Figure 13B). Calculated flow rates at Alcott Street ranged from 40 to 240 cfs, and calculated flow rates at Cork Street ranged from 34 to 112 cfs. Additional details regarding the findings of the surface water investigation are presented in *Technical Memorandum 11* (BBL, 2000a).

The Federal Emergency Management Agency (FEMA) conducted a study of Portage Creek for flood insurance purposes in September 1992 (FEMA, 1992), after the Bryant Mill Pond was drawn down but before the USEPA

Removal Action and the IRM. This FEMA study included the use of HEC-2, a one-dimensional, steady-state hydraulic model developed by the USACE Hydrologic Engineering Center that is frequently used for water surface elevation modeling in floodplain analyses. The HEC-2 model results indicated that the 100-year flood surface elevations ranged from 788.80 feet AMSL above the Alcott Street Dam, to 789.04 feet AMSL near the Type III Landfill, to 791.03 feet AMSL just downstream of the Monarch HRDL, to approximately 795.90 feet AMSL at Cork Street. These flood surface elevations may have changed slightly as a result of the USEPA Removal Action and the IRM.

The section of Portage Creek in the vicinity of this operable unit is a groundwater fed gaining creek. Portage creek has dominant influence over the site and a greater influence than any other regional controls in the basin. Site specific data have demonstrated groundwater heads above surface water elevation and groundwater springs break out at the surface and flow over land into the Portage Creek. A spring (commonly referred to within this RI as a groundwater seep) is a feature that exists when groundwater is under sufficient hydrostatic pressure enough to rise above the aquifer containing it. The subsurface transport path groundwater velocities associated with these features are typically strong enough to move upgradient soil/sediment particles to the surface. The velocities and the mass of material potentially transported in association with these features are not typical of normal groundwater flow. This process results in subsurface erosion that serves to develop a more efficient transport path for particulates to the surface. This process also results in surface flow and erosion which carries particulates (i.e., soils/sediments) toward and into Portage Creek. The particulates transported in the subsurface and surface by the springs/seeps will include those associated with the PCB contaminant.

3.2.4 Site Geology

The geologic history of the Allied OU is summarized in this section along with descriptions of the various geologic materials present and the conventions used in the geologic cross sections developed for this report.

3.2.4.1 Site Geologic History

As discussed in Section 3.1.3.2, the complex assemblage of overburden deposits underlying the site is the result of several episodes and modes of deposition. Chief among these were the latter stages of the Pleistocene glaciation, during which the margins of ice lobes advanced and retreated several times across the area. These actions left deposits of till, outwash, and in areas where meltwater was able to form lakes and ponds, silt and clay. In the roughly 15,000 years since the final retreat of ice from the area, Portage Creek has meandered through the current valley, downcutting into the glacial deposits and depositing intervals of alluvium within its channel and floodplain. These alluvial deposits consist primarily of layers of gravel, sand, and silt. Prior to development of the site, conditions along much of the creek's floodplain favored formation of peat and organic-rich silt. These peat and organic-rich silt deposits generally formed the surface soils in the floodplain to a depth of several feet. Development of the site involved the creation of Bryant Mill Pond and the disposal units; these activities inundated and buried much of the former floodplain area, altering the depositional environment. More recently, completion of the Removal Action and the IRM involved excavating, backfilling, and reworking sediments, fill materials, and native soils in portions of the floodplain. As a result, the stratigraphy along the creek is complex and composed of a variety of native and imported materials.

Cross sections A-A' through G-G' (Figure 15 through Figure 21) were prepared to help illustrate the distribution of the geologic units discussed in this section, and to aid in the evaluation of groundwater flow (Section 3.2.5.5). Figure 14 depicts the cross section lines in plan view. The cross sections are a simplified and extrapolated representation of the information provided in the boring logs, and were drawn using the conventions described in Section 3.2.4.3.

The origin of the various native deposits beneath the site (i.e., whether they are glacial or post-glacial) was not considered in defining the geologic units because this determination is rarely straightforward. For example, samples of glacial outwash and lake deposits retrieved from split-spoon samplers can be impossible to distinguish from similar water-laid deposits of non-glacial origin. Fortunately, making such a distinction is unnecessary because the information needed to help assess the nature and extent of site-related impacts and guide future remedial decisions relates to the physical properties and extent of geologic materials, not their origin. For these reasons, the types and extent of the various water-laid unconsolidated deposits (i.e., stratified sands, gravels, silts, and clays) are identified on the cross sections, but their origins are not. This approach is consistent with that used by the State of Michigan to develop its quaternary geology map, where glacial outwash sand and gravel and post-glacial alluvium are treated as one unit (Farrand, 1982).

The following subsection describes the nature of the various geologic units defined at the site.

3.2.4.2 Geologic Units

BBL identified seven geologic units based on information obtained from the boring logs provided in Appendix B. These logs were prepared over a period of 22 years by many different geologists whose understanding of site conditions varied considerably. The geologic units represent categories of the materials described in these boring logs, based on BBL's interpretation of the descriptions provided. These categories are primarily defined by texture (grain size) and origin (native soils and sediments vs. imported fill and residuals). Given the relatively complex geologic history of the site, there may be substantial spatial variation within some of the units. When defining the geologic units, color descriptions contained in the logs were not given much consideration because no standardized system (e.g., Munsell) was consistently applied to describe colors over the decades that data were collected.

The seven geologic units identified at the site and used in the cross sections are described below.

Fill

Various fill materials have been placed at the Allied OU during site development and during the various remedial actions completed to date. The fill unit shown on the cross sections consists of three types: fill used to form the berms of the Monarch and Bryant HRDL and FRDLs, fill placed in the Former Type III Landfill and Western Disposal Area, and backfill placed by the USEPA in the Former Bryant Mill Pond during the Removal Action.

The fill used to form the berms of the dewatering lagoons was obtained from a borrow pit located in the Western Disposal Area. The berm fill consists of loose, fine to coarse sand, generally some silt, little gravel, and trace clay. These berms have a high sand content and therefore these structures can significantly affect groundwater flow in the area. The table below summarizes relevant grain-size data for fill samples collected from the berms and other areas of the OU.

Summary of Fill Grain-Size Data

Sample	Depth (feet)	% Gravel	% Sand	% Fines
Berm Materials				
GEO-1	8-10	12	52	36
GWE-1	14-16	21.9	58.1	20
	16-18	6.9	70.4	22.7
GWE-2	18.8-19.4	25.5	59.0	15.5
	19.4-19.8	11.1	79.2	9.7
	20-22	32.8	50.4	16.8
SB-O	12-14	13	77	10
Former Type III Landfill				
GTNW	3-5	7.9	62	30.6
GTA-02	28-30	7.4	51	41.1
Sand Backfill				
MW-215	0-0.3	5.4	73.3	21.3
	0.3-2.2	14.3	72.8	12.9

The berm fill contains trace residuals mixed with the sand matrix (e.g., at the MW-204B location), thin to thick seams of residuals (e.g., MW-22AR, OW-5P), or thick deposits of residuals (e.g., MW-126A).

The fill in the Former Type III Landfill and Western Disposal Area contains silty fine-to-coarse sand mixed with or including discrete layers of, industrial wastes such as wood, cardboard, paper, plastic, slag, glass, bricks, and general refuse (e.g., at the MW-19B location). Residuals in this fill have been observed in several forms: in trace amounts mixed with the sand or industrial wastes (MW-19B), in seams of various thickness, or as thick (10 feet or more) relatively homogeneous layers (e.g., GTA-02, GTC-02).

The USEPA imported material used as backfill in the Former Bryant Mill Pond during 1998-1999. The material generally consisted of brown silty fine sand with trace to some gravel and trace clay. At the edge of the backfilled area, small nodules (1-3 inches) of residuals were observed to be sparsely intermixed with the backfill. The approximate extent of sand backfill is depicted in plan view on Figure 35A and Figure 35B. On the cross sections, the sand backfill is identified by yellow shading with black crosshatching.

Residuals

Residuals present at the site consist primarily of clay and wood fiber (BBEPC, 1992); however, thin intervals of sand or other fill are not uncommon in residuals deposits. As discussed in Section 1.2.2, prior to the mid-1950s residuals were discharged with wastewater into Portage Creek. After the mid-1950s, the wastewater generated at the Bryant and Monarch Mills was sent to a clarifier, and settled residuals were pumped to the HRDLs and FRDLs to dewater. Some of the settled solids in the HRDLs and FRDLs were then disposed of in the Type III Landfill and the Western Disposal Area. As a result, relatively thick deposits of residuals are present in the HRDLs, FRDLs, and the majority of the Type III Landfill and Western Disposal Area. The residuals in these areas are depicted on geologic cross sections A-A' through G-G' (Figure 15 through Figure 21). As shown on these cross sections, the layer of residuals appears to be thickest, approaching 20 feet, at the Monarch HRDL (boring MLSS-4) and in the Western Disposal Area (MW-120). Thin layers of residuals (less than one foot) are also present at the site, especially in the berm fill, but are too numerous and hydraulically insignificant to be shown on the cross sections.

Historical deposits of sediments in the Former Bryant Mill Pond also contained residuals; however, these were excavated during the USEPA Removal Action.

Peat

Peat at the site consists of post-glacial-age deposits of organic matter (fibrous to non fibrous texture) that contain varying amounts of silt and clay. The composition of the peat varies spatially between a gray-colored, organic-rich clayey silt and a brown-colored fibrous peat. These changes in composition appear to be gradual rather than sharp, and follow no discernable pattern. The peat formed along the floodplain of Portage Creek, which was modified as the site was developed, operated, and then closed. Filling and regrading of floodplain soils, formation and subsequent draining of the Bryant Mill Pond, and recent response actions have all modified the floodplain. These modifications resulted in the burial of peat in some areas, and partial or complete removal in others.

Figure 22 depicts the extent and thickness of the peat. The figure shows that the peat:

- is typically less than 3-feet thick, and its thickness generally decreases with distance from the creek;

- extends further from the creek along its west bank (typically 300 to 400 feet) than along its east bank (typically 200 feet or less);

- underlies the Monarch HRDL; portions of the Bryant HRDL; FRDLs 1, 3, and 5; the Type III Landfill; and the Western Disposal Area; and

- is locally absent at several locations. Two of these locations, which are defined by more than one data point, appear to be somewhat larger than the others. They are located along the sheetpile wall, one between monitoring wells MW-204B and MW-211 and the other between monitoring well MW-208 and soil boring SB-A.

As noted on Figure 22, the extent and thickness of the peat beneath the Former Bryant Mill Pond is not well understood, in part due to the changes resulting from the USEPA Removal Action. The USEPA generally excavated residuals down to the upper surface of the peat, leaving it intact. However, where confirmation samples indicated PCB concentrations greater than target levels, they frequently breached the peat during re-excavation. Descriptions of the materials at the base of the excavation in this area are not available, and few borings have been drilled inside the post-excavation boundaries.

Sand and Gravel

As shown on the cross sections, deposits of sand, gravel, and mixtures of the two are common at the site. Sand deposits consist of layers of well-to-poorly sorted fine to coarse sand, silty sand, and gravelly sand. Occasional lenses of silt or clay are not uncommon. The percentage of fines in the sand deposits varies widely, both spatially and with depth, ranging from just a few percent to over 30 percent by weight in samples analyzed for grain size (Table 3-2A). Deposits of gravel are less common, and contain various amounts of fine to coarse sands with little-to-trace amounts of fines. Gravels are composed of various rock types and exhibit various degrees of rounding. The relative density of the sand and gravel deposits is variable, ranging from loose (penetration-resistance "N" values of 2 to 4) to dense (N values of 30 to 50). The color of the sand and gravel deposits is variable, ranging from shades of gray to shades of brown. The extents of the sand deposits are discussed further in Section 3.2.5.1.

Silt

Deposits of silt beneath the site are generally described as gray-to-brown in color, with varying amounts of fine-to-coarse sand and clay, which sometimes occur in the form of thin lenses or partings. The deposits are generally very stiff to hard, with N values that are typically 15 or higher. The relationship of the silt deposits (as well as the clay and till deposits, which are described below) to other deposits at the site are discussed in greater detail in Section 3.2.5.2.

Clay

Clay deposits beneath the site, like the silt deposits, range from gray to brown in color and contain varying amounts of fine-to-coarse sand and silt, sometimes in the form of lenses or partings. The consistency of the clay deposits is variable, typically ranging from medium stiff (N values of 4 to 8) to hard (N values >30).

Till

Till beneath the site can be described as a generally unsorted deposit of fine sand, silt, and/or clay in varying proportions. The till contains lesser amounts of medium-to-coarse sand and gravel, and sometimes contains discontinuous lenses of silt, sand, and/or gravel. The till is typically very stiff (N values between 15 and 30) to hard (N values >30). Clasts in the till tend to be angular to subrounded.

3.2.4.3 Development of Cross Sections

BBL used a series of conventions when developing the cross sections to promote uniformity and help maximize their usefulness. This standardized process was particularly important given the large volume of available data, the long period over which data were collected, and the relatively large number of geologists involved in collecting and recording the data. The conventions are summarized below:

- Soil boring logs for the site were reviewed to assess which logs described subsurface conditions most consistently and accurately. Logs that contained the most detail and were generated from recently drilled borings by a geologist still employed by BBL who could be interviewed by the cross-section developers were relied upon more than those with relatively little detail (e.g., standard rather than continuous sampling) and from borings drilled early on in the project.

- For soil boring "clusters" (e.g., where two or more borings are located near each other), the log for the boring located nearest to the line of section was the primary source of data.

- Soil units with a thickness of one foot or greater were depicted on the cross-sections.

- When correlating stratigraphic units, BBL assumed that no major faulting/overturning of geologic deposits occurred (i.e., the oldest deposits were assumed to be stratigraphically lower). While it was noted that in an ice-contact setting such as at the site this assumption may not always be valid, the boring logs reflected this interpretation.

- Horizontal lithologic boundaries were depicted with dashes where inferred. Vertical discontinuities, particularly in areas of sparse data, were represented as a jagged line composed of dashes. The location of the vertical discontinuity was plotted at the midpoint between the boring where the unit occurred and the adjacent boring where it did not.

- The limits of dikes and other areas of fill were inferred based on site construction knowledge and comparison with historical aerial photos and topographic maps.

- The representative fill color for the units was hatched when approximately equal amounts of different-sized materials (e.g. sand and silt) were indicated in the boring log(s). Hatching was also used to depict "interbedded" deposits on the sections. A description of interbedded deposits is provided below.

- The "lower limit of information," depicted as a bold, dashed line on the cross sections, was inferred to be 5 feet below the total depth of the borings used to develop the section. In some cases, deeper borings located off-section provided additional data. In these cases, the lower limit of information was adjusted downward to reflect this additional information.

BBL worked closely with the MDEQ in developing the cross sections. The MDEQ helped select the orientation of the cross-section lines, and reviewed and commented on the cross-section conventions as well as initial drafts of the cross sections themselves.

3.2.4.4 Geotechnical Characteristics of Site Deposits

As discussed in Section 2.2.3, the primary goals of the geotechnical investigation were to collect data to evaluate the stability of the HRDL and FRDL berms and assess the geotechnical feasibility of various remedial alternatives. The information gathered during five phases of the geotechnical investigation conducted at the site over the last 10 years is sufficient to meet these goals. While the results will be most relevant during the FS and remedial design phases, brief descriptions of the geotechnical properties of the fill, residuals, peat, sand and gravel, silt, clay, and till, geologic units (as established for the geologic cross sections) developed from the results of geotechnical sampling are presented below. The geotechnical sampling locations are shown in Figure 7. Results of the five phases of investigation are summarized in Table 3-2A through Table 3-2D, and complete results are contained in Appendix D. (Results from the first two phases of investigation were previously reported in Section 3.2 and Appendix H of *Technical Memorandum 7* [BBL, 1997c], and a July 1, 1998 letter to the MDEQ [Brown, 1998b], respectively.)

Fill and Sand

Both the fill and sand units were generally classified as a silty sand, containing more than 20% gravel in some locations. The direct shear testing of the fill and sand units indicated peak friction angles of 43.8 and 35 degrees, respectively, which means that under ideal conditions, the fill and sand units could be successfully cut or graded at a slope of approximately 2:1 horizontal to vertical (H:V).

Peat

The organic silt and clay rich peat (non fibrous) unit at the site has variable water content and a consistently low dry unit weight. Atterberg Limit testing (i.e., liquid and plastic limits) indicated that the non fibrous peat is generally highly plastic; however, the results also indicated variability in liquid and plastic limit values. This was confirmed with the calculation of the liquidity index, which is used to evaluate general soil behavior under a shearing load. The results indicated that when sheared, the geotechnical behavior of the peat would most likely vary across the site from a plastic to a viscous liquid. Finally, strength testing (i.e., unconsolidated-undrained triaxial compression testing) resulted in a maximum compressive strength of 4,190 pounds per square foot (psf). This means that the peat is relatively stiff; however, settlement during loading may be influenced by the organic decomposition of the material.

Clay and Silt

The clay samples collected were generally of low plasticity, and the consolidation characteristics of the unit showed little variation across the site. In comparison, the silt layer is nonplastic with over 30 percent fines (i.e., clay and silt). An interbedded unit consisting of alternating layers of silt and clay and/or silty sand was also sampled, and the material varied from nonplastic silt to a low plasticity clay. The water content was fairly consistent, but the amount of fines varied widely from 23 to 80%.

Till

Test results for the till unit present in certain areas of the site indicate a range in both fines content and moisture content. Typically, the samples with higher moisture contents also had a higher percentage of fines. Direct shear testing indicated a peak friction angle of approximately 39.8 degrees which, similar to the fill and sand units, means that under ideal conditions the till unit could be successfully cut or graded at a slope of approximately 2:1 H:V. Unconfined compression testing performed on the till unit material showed the maximum compressive strength increased with depth and ranged from 2,300 psf to 7,780 psf, indicating a medium compact to very compact material.

Residuals

Residuals samples generally had high organic contents (i.e., greater than 40%) and water contents (i.e., greater than 100%[2]). Samples collected from the berms reflected a lower water content than samples from the Monarch HRDL, most likely the result of the residuals unit being thinner (i.e., 4 feet or less), more compacted, and located between sand layers, which results in better drainage. The Atterberg Limits testing indicates that the residuals are highly plastic; however, the liquidity index calculations indicate that the behavior of the residuals under a shearing load most likely varies across the site (i.e., the residuals may behave like a plastic or a viscous liquid when sheared).

Finally, unconsolidated-undrained triaxial testing and vane shear testing indicated that the residuals are soft and weak. The generally low strength of the residuals in the Monarch HRDL must be taken into consideration in future evaluation of remedial measures to cap the waste and stabilize the berm of this study area.

[2] Water content can exceed 100% in solids samples because it is calculated as the weight of water in a sample divided by the weight of the solids in the sample. If the solids are not very dense (as with the residuals) and the sample is saturated, the weight of the water can exceed the weight of the solids and the resulting water content will be greater than 100%.

3.2.5 Site Hydrogeology

The focus of this section is to explain the origin of groundwater beneath the site and how it moves through the subsurface. Emphasis is given to the area near Portage Creek, where site groundwater discharges, and where the greatest concentration of data exists. The effects of the IRM activities are also evaluated, as appropriate.

The discussion draws from several sources of information, including:

- The regional hydrogeologic model presented in Section 3.1.4;
- The understanding of site-specific geology developed in Section 3.2.4;
- Hydraulic conductivity data for various geologic deposits beneath the site; and
- Water levels obtained from site monitoring wells, piezometers, and Portage Creek.

The subsurface materials at the site can be divided into two broad classes based on their water-transmitting properties. This division is useful in developing a meaningful description of the complex stratigraphy of the site and assessing the potential migration pathways of site-related constituents in the subsurface. The first class is the *transmissive* deposits – deposits of primarily sand, gravel, or a mixture of the two, and fibrous peat that transmit water reasonably well (i.e., the hydraulic conductivity of these deposits is moderate to high). Most of the groundwater moving through the site, at least to the depths investigated, passes through these materials, and nearly all existing site monitoring wells are screened in these deposits. It should be noted that the fibrous peat is a transmissive deposit but was not necessarily targeted for well construction. The second class includes deposits with poor water-transmitting properties (i.e., low hydraulic conductivity). Referred to as *aquitards*, these are deposits that are composed primarily of fine-grained materials (silt, clay, till, non-fibrous peat, and residuals). Though relatively little groundwater moves through the aquitards, they can divert groundwater flow and, where they are laterally extensive, can serve to hydraulically separate the more transmissive units. The characteristics of the deposits in each class are discussed below, followed by descriptions of hydraulic conductivity (Section 3.2.5.3), water-level data (Section 3.2.5.4), and groundwater occurrence and flow (Section 3.2.5.5).

3.2.5.1 Transmissive Deposits

Transmissive deposits beneath the site are composed mainly of well to poorly-sorted fine to coarse sand and/or gravel, including fill that does not contain residuals. Many of these deposits contain a considerable fraction of silt or clay. In some cases the silt and clay can be attributed to stratification, where lenses of silt and clay are present in the sand. In other cases, it appears that the sand deposits are a more uniform mixture of sand, silt, and/or clay. The majority of the sand and gravel deposits depicted on the cross sections most likely represent glacial outwash. The exception would be near Portage Creek, where some post-glacial alluvium has been deposited.

The transmissive deposits can be broadly divided into three hydrostratigraphic units: upper sand, intermediate sand, and lower sand. Hydrostratigraphic units comprise geologic units of similar hydrogeologic properties (e.g., hydraulic conductivity); therefore, several geologic units can be grouped together as one hydrostratigraphic unit. The concept of hydrostratigraphic units was introduced by Maxey (1964) and reassessed by Seaber (1988), and can be used to aid interpretation and simplify the discussion of groundwater flow. The balance of this subsection describes relevant characteristics of these three units, and how they are distributed across the site.

Upper Sand

The upper-sand unit consists of saturated sand, gravel, and/or fill deposits. Based on field observations and grain-size analyses performed on samples of this unit (Table 3-2A), the majority of the upper-sand unit contains appreciable quantities of fine sand, silt, and clay. This unit occurs either at the surface or directly beneath deposits of residuals or peat.

Along the west side of Portage Creek near the Bryant HRDL and FRDLs, fill (and in some cases residuals) has been placed on top of the peat that once formed the original land surface of the creek's floodplain. As a result of this placement, the water table occurs within the fill layer. The upper-sand unit in this area includes a layer of saturated fill separated from the uppermost native sand by the peat. A groundwater recovery system installed as part of the IRM to mitigate groundwater mounding behind the sheetpile serves to reduce the saturated thickness of the upper-sand unit in the area near the Bryant HRDL and FRDLs.

The upper-sand unit appears to be continuous beneath the site and varies in thickness. Near the southwestern site boundary along Portage Creek, aquitards are absent beneath the peat (refer to Figures 16, 18, and 19; cross sections B-B’, D-D’, and E-E’, respectively); therefore, the upper-, intermediate-, and lower-sand units can be thought of as one unit in this area. Generally within upland areas located west of Portage Creek, this upper-sand unit is relatively thick with the water table being located within native sand. In other areas, the majority of the unit is unsaturated. This relationship is shown on Figure 17 and Figure 31 (cross section C-C’ and its associated flow net). Closer to the creek, the thickness of this upper sand unit decreases since the till and other aquitards are encountered at shallower depths. In areas of the site where fill[3] has not been placed (primarily north of the Type III Landfill, along the floodplain), the water table resides near the land surface, either in the upper-sand unit or in the overlying peat.

Intermediate Sand

The intermediate-sand unit consists of lenses and stringers of sand or gravel deposits that occur within aquitards, chiefly between elevations of 755 to 780 feet AMSL. Examples include the sand lenses screened by wells MW-209, MW-211, and MW-213 (refer to Figure 18 – cross section D-D’). Correlation of these deposits from one borehole to another is not always possible, implying that this unit may be discontinuous. Some of the deposits included in this unit are composed of sand interbedded with silt, and occasionally clay seams. Based on field observations made during the RI, the texture of the intermediate sand unit is similar to the upper-sand unit; generally containing an appreciable quantity of fine-grained materials.

As noted above, these units are not separated by an aquitard along the creek in the southwest portion of the site. Along the creek in the southeast portion of the site, aquitards underneath the peat are absent below elevation 760 AMSL (see Figure 18, cross section D-D’). As a result, the intermediate- and lower-sand units could be considered as one unit in this area.

Given the nature of the intermediate-sand unit (i.e., lenses and stringers of sand or gravel), it is likely that some of the lenses are hydraulically connected to the upper-sand unit. In fact, hydraulic head and chemical data for wells screening the units suggest that, at some locations, the two units are not separated. The hydraulic and chemistry data for these units are discussed in greater detail in Sections 3.2.5.2 through 3.2.5.5 and Section 4.4.

Lower Sand

The lower-sand unit is interpreted to consist of an apparently continuous deposit of sand that underlies the known aquitards at the site. Given its depth, fewer borings have penetrated this lower-most unit than the other

[3] Except for fill placed by the USEPA as part of the Removal Action (see Section 1.2.3.1 for details). This fill is depicted on the cross sections as “Sand Backfill.”

units; as a result, information on its aerial and vertical extent and continuity are limited. In areas where it is distinctly separate from the intermediate unit (see the bottom portion of cross section D-D’ shown in Figure 18), the elevation of the upper surface of the unit ranges from approximately 750 to 725 feet AMSL. Only the uppermost few feet of this unit have been penetrated by these investigatory borings.

3.2.5.2 Aquitards

Aquitards beneath the site consist of residuals, non fibrous peat, till, clay, and silt deposits. These deposits can be grouped into the following four hydrostratigraphic units: residuals, peat, upper aquitard, and lower aquitard. The balance of this subsection describes the relevant characteristics of these hydrostratigraphic units.

Residuals

The residuals hydrostratigraphic unit consists of those portions of the relatively thick and contiguous deposits of residuals found in the HRDLs, FRDLs, Type III Landfill, and Western Disposal Area that occur below the water table. These deposits are divided in places by the berms that form the HRDLs and FRDLs.

Peat

The peat consists of the peat unit described in Section 3.2.4.2. In locations where the peat is fibrous, the peat is not an aquitard. Where the peat underlies residuals and its composition is a silty clayey peat, this peat will affect groundwater flow and may serve as an aquitard between the fill and underlying native-sand deposits or other more coarse grained deposits.

Upper Aquitard

The upper aquitard is formed of till, silt, and clay deposits that tend to abut or overlap one another, forming a semi-continuous unit across much of the site. This aquitard generally separates the upper- and intermediate-sand units described in the above Section 3.2.5.1. For this reason, the balance of this subsection focuses on where the unit is absent. The elevation and thickness of the aquitard varies somewhat, although it generally occurs between an elevation of 795 to 765 feet AMSL.

The upper aquitard is absent in a few areas, as can be seen on several of the geologic cross sections prepared for this report. One such area is at the southern end of the site, located along Portage Creek. Figures 15, 16, and 19 (cross sections A-A’, B-B’, and E-E’, respectively) show that the aquitard in this area. The aquitard in this area is comprised of till and pinches out from north to south approaching the creek. Cross section D-D’ (Figure 18), which parallels the creek and is perpendicular to cross sections A-A’, B-B’, and E-E’, shows that the aquitard is absent from approximately the PS-8 location westward (moving toward the left on the cross section) to the end of the section, a distance of about 600 feet.

Another area where the upper aquitard is absent can be seen on Figure 16 (cross section B-B’). Near the north end of this cross section, the aquitard is absent beneath the Former Bryant Mill Pond and Type III Landfill. This absence appears to continue northward along Portage Creek, as logs for deep borings in this area (e.g., MW-114, and SB-2006 through SB-2009) reveal surface elevations for the first clay deposits encountered lower than about 760 feet AMSL.

The last area where the upper aquitard is absent is near boring location SB-102. Cross sections A-A’, C-C’, and F-F’ (Figures 15, 17, and 20, respectively) all intersect at SB-102 which depicts the relationship between the transmissive units and aquitards in this area. From these cross sections, it appears that the area where the upper aquitard is absent is limited to within a few hundred feet of the boring. A lower aquitard (discussed below) is present beneath this area.

Lower Aquitard

The lower aquitard beneath the site consists chiefly of deeper till and clay deposits. The upper surface of the aquitard generally lies between approximately 770 and 755 feet AMSL, and the unit is typically more than 10 feet thick. Fewer data are available for the lower aquitard than for the upper aquitard. For this reason, the extent and continuity of the lower aquitard are less well defined. The relationship of the lower aquitard to other units beneath the site, as well as the general vertical limits of available data, can be seen on cross sections A-A’, C-C’, D-D’, and F-F’ (Figures 15, 17, 18, and 20, respectively).

The relevant geologic information for the lower aquitard is summarized below:

- Beneath the Former Type III Landfill and extending northward to at least former monitoring well MW-18, the aquitard is composed of clay (or silt at MW-18). The unit was penetrated at four locations: MW-16C, MW-18, MW-19D/MW-19BR, and SB-102.

- Toward the east, beneath the Bryant HRDL and FRDLs along the sheetpile that parallels Portage Creek, the aquitard consists of interbedded clay, silt, and sand seams and/or till and is present at monitoring well MW-204B, extending northward to at least monitoring well MW-122B. A number of wells/borings penetrate the aquitard in this area. South of monitoring well MW-122B, at soil boring SB-D, the aquitard is quite thin (about 5-feet thick). At monitoring well MW-122B, the intermediate-sand unit is absent and the upper and lower aquitard are joined (see Figure 18 - cross section D-D') with a combined thickness of nearly 30 feet, but it is likely not extensive.

- As shown on Figure 17 and Figure 20 (cross sections C-C' and F-F', respectively), the degree to which the lower aquitard is continuous between the Former Type III Landfill and the Bryant HRDL and FRDLs is unknown. Three monitoring wells (MW-122B, MW-204B, and MW-205B) located generally downgradient of both the Former Type III Landfill and the Bryant HRDL and FRDLs are used to monitor the lower-sand unit that underlies the aquitard. As discussed sections 4 and 5 of this report, the water quality at one of these wells (MW-122B) may be impacted by historical activities at the Allied OU, suggesting that the aquitard may be locally absent.

- Westward, beneath the Western Disposal Area, no borings were drilled below an elevation of about 770 feet AMSL; therefore, it is uncertain whether the aquitard is present in that area.

Toward the south, beneath the remaining areas of the Bryant HRDL and FRDLs and across Portage Creek to the Monarch HRDL, the aquitard is either absent, or its surface occurs beneath approximately 750 feet AMSL, which is the approximate extent of the deeper borings in that area (see cross section D-D' on Figure 18). As noted previously, the upper aquitard is also absent in this area. As a result, it appears there is no aquitard to redirect or influence the groundwater flow path to surface water in these historical disposal areas.

3.2.5.3 Hydraulic Conductivity

Hydraulic conductivity (*K*) is a measure of the extent to which a given geologic material allows water to flow through it, and is determined by such factors as grain sorting, size, and shape. BBL used several approaches to estimate the *K* of various geologic materials beneath the site. These approaches consisted of performing rising-head ("slug") tests or specific-capacity tests in selected monitoring wells, and calculating *K* using soil grain-size distribution or consolidation test data. The available *K* data for the site, including the methods used to analyze the test data, are discussed below and summarized in Table 3-3.

<u>Methods</u>

BBL performed slug tests or specific-capacity tests at 34 wells and piezometers, most of which are screened across multiple geologic materials (e.g., "fill and peat" or "sand and till"). In such cases, the percentage of the test interval occupied by the various materials is specified in Table 3-3. When *K* tests are performed in wells screened across different geologic materials, the resulting estimated *K* value reflects the average *K* of all the materials included in the interval tested. This makes it difficult to estimate the true *K* of the different geologic materials included in the test interval. For example, consider a test conducted on a well that screens equal thicknesses of materials with highly contrasting hydraulic conductivities (e.g., sand and clay). When a slug of water is removed from the well, a disproportionately large percentage of the water that enters the well from the screened interval will be provided by the sand rather than the clay. In this case, the calculated *K* value will be more representative of the sand than the clay, but will underestimate the true *K* of the sand.

Because the *K* of granular porous media is related to the grain-size distribution (Freeze and Cherry, 1979), rough estimates of *K* can be made from grain-size distribution data. BBL used the Beyer Method (Vukovic and Soro, 1992) – which is valid only for soils with particulate sizes in the fine sand to gravel range – to estimate the hydraulic conductivity of the 19 samples (out of 73 collected) analyzed for grain-size distribution that met the criteria of the method. The estimated *K* values for these samples are included in Table 3-3. Details regarding the calculations are contained in Appendix D.

Hydraulic conductivity can also be estimated from consolidation-test data using the method described by Lambe and Whitman (1969). Consolidation tests were performed on ten samples of residuals. The estimated *K* values for these samples are included in Table 3-3.

The *K* results are discussed below for each of the various hydrostratigraphic units at the Allied OU (i.e., the transmissive deposits and the aquitards).

<u>Transmissive Deposits</u>

Upper-Sand Unit

A number of *K* estimates are available for the upper-sand unit, as summarized Table 3-3. The geometric mean of estimated *K* values derived from in-well tests (i.e., slug and specific capacity tests) is 1.7×10^{-3} centimeters per second (cm/s), an order of magnitude lower than the geometric mean calculated using the grain-size distribution analysis data (2.5×10^{-2} cm/s).

It is clear that the hydraulic conductivity of the upper-sand unit varies considerably across the site. Conductivity from slug test data rages range between 1.7×10^{-2} to 4.9×10^{-5} cm/s (Table 3-3). This is expected because available data suggest that the unit is hydraulically heterogeneous and likely anisotropic. The heterogeneity is caused by the variations in grain size distribution of the materials comprising the unit, while the anisotropy would be expected due chiefly to the small-scale interbedding of coarser and finer layers that is typical of glacial meltwater deposits (Stone and Dickerman, 2001). This interbedding causes groundwater to flow preferentially in the horizontal direction along coarser layers between finer-grained beds that impede flow in the vertical direction[4]. Anisotropy results in the unit having a higher hydraulic conductivity in the horizontal direction (K_h) than in the vertical direction (K_v). In-well tests provide an estimate of K_h, and K_v can be estimated from the literature. This difference between K_h and K_v is often expressed as a ratio, K_h:K_v, known as the anisotropy ratio. Stone and Dickerman (2001) estimated the anisotropy ratio for a glacial sand and gravel aquifer in Rhode Island to range from 5:1 to 125:1, meaning that the K_h was 5 to 125 times greater than K_v. In their *Manual of Groundwater Hydrology*, the USACE notes that it is not uncommon for sites with layered heterogeneity to have anisotropy values of 100:1 or greater (USACE, 1999). A reasonable estimate of the anisotropy ratio for the upper-sand unit at the Allied OU is 10:1. Considering the ranges of anisotropy ratios from the literature, this estimate is likely conservatively low, and the true anisotropy ratio is likely higher.

Based on the above information, a reasonable, conservative estimate of the typical K_h of the upper-sand unit is the geometric mean of the in-well *K* tests performed at the site, 1.7×10^{-3} cm/s.

Intermediate-Sand and Lower-Sand Units

Hydraulic conductivity tests were not performed in wells screened predominantly in the intermediate-sand unit and lower-sand units; however, three grain-size analyses for samples collected from the unit met the requirements of the Beyer Method (GTA-02, GTC-02, and GWE-3; see Table 3-3). The geometric mean *K* for these three samples is 1.3×10^{-2} cm/s.

Peat as Transmissive Deposit

No monitoring wells or piezometers are screened entirely in the peat, and the Beyer Method is not appropriate for peat samples; therefore, no site-specific measurements of the *K* of the peat layer are available.

Based upon the gradation characteristics of the peat it is reasonable to assume that the fibrous peat has a hydraulic conductivity value comparable to the adjacent transmissive units. Like wise a non fibrous peat will likely have a lower hydraulic conductivity value then the fibrous peat.

[4] Anisotropy also may be due to the horizontal orientation of elongated, plate-shaped grains, which causes the hydraulic conductivity of individual beds in the aquifer to be lower in the vertical direction.

Aquitards

Residuals

Paper-making residuals typically have a high clay content, and therefore have long been recognized as materials that would tend to impede water flow. Since 1984, the National Council of the Paper Industry for Air and Stream Improvement (NCASI) has sponsored research to assess the potential for residuals to serve as hydraulic barrier construction material. One component of the research involved a laboratory study designed to estimate the *K* of residuals and other paper-making byproducts (NCASI, 1989). Another component consisted of an eight-year field study that included estimating the *K* of residuals placed in test cells designed to simulate a landfill cap (Maltby and Eppstein, 1996). The *K* values resulting from the two phases of the NCASI research, which are presented in the table below, are quite low. The researchers from Western Michigan University in Kalamazoo who conducted the field study concluded that residuals can be suitable for constructing hydraulic barriers at landfills (Maltby and Eppstein, 1996).

BBL estimated the *K* of residuals at the Allied OU using consolidation-test data according to the method described by Lambe and Whitman (1969). The results, included in the adjacent table, are within the range of the *K* values resulting from the NCASI research. These tests were performed on 10 samples of residuals collected at four locations in the Bryant HRDL and FRDL 5.

Hydraulic Conductivity Estimates of Residuals

Source	Method	n	Geometric Mean *K* (cm/s)
NCASI Laboratory Study (1989)	Fixed-wall permeameter	13	1.8E-06
NCASI Field Study (1996)	Water balance[1]	2	2.1E-07
	In-situ SDRI[2]	2	3.5E-07
	In-situ TSB[3]	2	1.7E-07
	Flexible-wall permeameter[4]	2	5.7E-08
Allied OU	Consolidation-test data	10	1.3E-07

Notes:
[1] *K* value represents the geometric mean of 8-year average *K* values for 2 test cells (Maltby & Eppstein, 1996).
[2] SDRI = scaled double-ring infiltrometer.
[3] TSB = two-stage borehole permeameter.
[4] These samples permeated at effective stress equivalent to field conditions.

The hydraulic conductivity of soft compressible materials such as residuals is affected by their degree of consolidation. As residuals consolidate, their *K* decreases (Moo-Young and Zimmie, 1996). This is significant at the Allied OU because it suggests that at the HRDLs and FRDLs, where residuals are quite thick, the *K* of the residuals would likely decrease with depth and over time, as consolidation proceeds. The placement of 146,000 cy of soil and residuals excavated during the Removal Action in the Bryant HRDL and FRDLs combined with the additional burden of a landfill cap over the area has increased the effective stress on the underlying residuals. This should cause the residuals to dewater and consolidate over time, further reducing their *K*. Additionally, Moo-Young (1995) showed that as the organic fibers in residuals decompose and dewater under pressure, the percent clay content increases and the *K* of the residuals decreases. Landfill gas detected in the gas vents of the landfill cap provides evidence that such decomposition is occurring.

Peat as Aquitard

No monitoring wells or piezometers are screened entirely in the peat, and the Beyer Method is not appropriate for peat samples; therefore, no site-specific measurements of the *K* of the peat layer are available.

Based upon the gradation characteristics of the peat it is reasonable to assume that the fibrous peat has a hydraulic conductivity value comparable to the adjacent transmissive units. Like-wise a non fibrous peat will likely have a lower hydraulic conductivity value then the fibrous peat.

Upper and Lower Aquitards

Site-specific measurements of the *K* of the upper and lower aquitards are limited to one value derived from a specific-capacity test conducted in monitoring well MW-1, which is screened in a silt layer interpreted to form part of the upper aquitard. The true nature of the screened interval at this location is unclear, however, because the boring for the well was not continuously sampled. The *K* value calculated from the test data at MW-1 is $9.2x10^{-4}$ cm/s. This value is at the high end of the typical range of $1x10^{-3}$ to $1x10^{-5}$ cm/s expected for silt, clay, and mixtures of sand, silt, and clay (Brassington, 1988). The *K* value derived at monitoring well MW-1 may be biased high due to the presence of sand or gravel lenses located in the portion of the screened interval that was not sampled. Given the generally dense, fine-grained nature of the till and clay deposits forming the bulk of the upper and lower aquitards, their bulk *K* is expected to be toward the low end of the range described in Brassington (1988).

3.2.5.4 Water-Level Data

This section describes the various water-level monitoring activities conducted at the Allied OU since 1993 and presents the collected data.

Groundwater and Surface-Water Elevations

Water levels (i.e., groundwater and surface-water elevations) were measured at monitoring wells and staff gages and used to evaluate groundwater flow patterns at the Allied OU. These elevation data were calculated using reference point elevations surveyed in feet AMSL using the national geodetic vertical datum (NGVD) of 1929.

From 1993 through 1999, BBL collected periodic water-level measurements from selected monitoring wells and one staff gage (CG-1). Water-level measurements at CG-1 (located in Portage Creek near the northern edge of FRDL 1) were compared with measurements at nearby monitoring well MW-122A to demonstrate that the direction of groundwater flow was toward the creek during groundwater sampling events. The water-level measurements collected during this time period generally correspond with the dates of groundwater sampling events, and are presented in Table 3-4A. Data between 1999 and 2000 were not collected apparently due to the Removal Action and IRM at the site.

Water levels monitored between January 2001 and July 3, 2001 were recorded on a weekly basis, then generally on a monthly basis through September 2006 as presented in Table 3-4C at the following locations:

- Selected monitoring wells and piezometers listed in Table 3-4C (note that the list was modified over time as wells were added, replaced, or decommissioned);
- Staff gages located in FRDLs 1 and 2. These gages were frequently damaged (due to ice heave or other causes). These data were no longer collected after June 2003 since these areas FRDL were filled in and/or re-graded due to the construction of the sedimentation basins in 2004;
- Upstream staff gage (SG-2), located in Portage Creek near Cork Street;
- Mid-stream staff gage (SG-1), located in Portage Creek near the northern edge of FRDL 1; and
- Downstream staff gage (Alcott St. bridge), located in Portage Creek near Alcott Street.

Groundwater and the Groundwater Recovery System

Between January and December 2000, BBL collected weekly water-level data at selected locations to help assess the performance of the groundwater-recovery component of the IRM. The groundwater and surface-water elevation data collected during this period are provided in Table 3-4B. The groundwater recovery system currently consists of two groundwater extraction wells (GWE-1A and GWE-4A); lateral collection trenches extending from six sumps along the landward side of the sheetpile wall (PS-1 through PS-5 and PS-9); and four sumps without lateral collection trenches (PS-6, PS-7, PS-8, and PS-10). All of the water collected by the ten sumps is routed to the main sump (MS-100) located near the downstream end of the sheetpile wall, then pumped to the on-site water-treatment system. The locations of the sheetpile wall and the components of the groundwater recovery system are illustrated on Figure 3.

The groundwater recovery system was installed and modified while the IRM was being constructed. The components of the groundwater recovery system, which are described in more detail in Appendix F, are summarized below.

- Two extraction wells (GWE-1A and GWE-4A), permanent sumps PS-1 through PS-5, and temporary sumps TS-6 through TS-10 were installed between May and December 2000;

- Permanent sumps PS-6 through PS-10 were installed during November 2002 to replace temporary sumps TS-6 through TS-10;

- A groundwater interceptor trench that drains into PS-1 was installed around the west and south sides of FRDLs 1 and 2 in November 2002; and

- A lateral collection trench extending in the upstream direction from PS-9 was installed in August 2003.

The effectiveness of the groundwater-recovery system is further discussed in Appendix S.

The total yearly flows (in million gallons) obtained from the Kalamazoo Water Reclamation Plant based upon MHLLC operator reported data for the period from July 1996 to September 2006 is summarized in the table below. Construction of the cap began in 2000 and was completed along with the sedimentation basin in 2004.

Reported Yearly Flows – Groundwater Recovery System (1999 through 2006)

Reported Value	1996 (Starting July)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006 (Ending September)
Total Flow (Million gallons)	0.48	1.11	1.52	3.44	12.11	22.86	19.88	17.56	7.74	9.32	5.99

Gas Vent Water Elevations

Subsequent to partial construction of the landfill cap over the Bryant HRDL and FRDLs, water was observed to have accumulated within the landfill gas vents. This water possibly originated from consolidation and dewatering of the residuals (especially the saturated sediments dredged from the Former Bryant Mill Pond during the USEPA Removal Action) and/or precipitation during construction of the landfill cap. Table 3-5 presents available monthly water level measurements in the gas vents gathered between October 2001 and May

2003. Overall, the water levels dropped slightly or were stable over the time period in question. Where the recorded water level within the vent indicated that the vent screen was completely submerged, the vent is unable to serve its function to allow the venting of gases, produced by the residuals.

Seep Water Levels

Groundwater seeps have been observed at the OU since the mid-1980s (BBEPC, 1992). The presence of springs/seeps on the banks of Portage Creek are characteristic of groundwater fed drainage systems. The presence of these features is consistent with Portage Creek acting as a local groundwater discharge zone. As discussed in Section 2.4.9, several groundwater seeps became apparent at the site in 1999 after the USEPA Removal Action. These new seeps appear to have formed as groundwater migrating toward Portage Creek encountered the compacted silty sand placed as backfill into the Former Bryant Mill Pond, which appears to be less transmissive than the Type III Landfill fill material and/or native floodplain deposits. BBL, in cooperation with the MDEQ, devised a plan (Cowin, 2002c) for collecting representative seep samples that involved installing temporary wells consisting of very shallow PVC screens and risers surrounded by a thick sand pack (see Section 2.4.9 and Appendix C for details). The locations of the temporary seep wells are shown on Figure 8. Available water levels at the seep wells were measured monthly by LTI-LimnoTech from January to June 2003 as shown in Table 3-6.

3.2.5.5 Groundwater Occurrence and Flow

Groundwater Occurrence

Groundwater beneath the Allied OU is derived from infiltration of precipitation falling on uncapped portions of the site and from groundwater entering the site from areas of higher hydraulic head. These areas are generally the uplands west and southeast of the Allied OU on the other side of Portage Creek. Given their low hydraulic conductivity, little recharge likely occurs through deposits of residuals (e.g., the Monarch HRDL). As described in above Section 3.2.5.1 and Section 3.2.5.2, multiple hydrostratigraphic units exist at the site. The uppermost transmissive unit, the upper sand, is unconfined, except where it is overlain by residuals or peat overlain by lower hydraulic conductivity materials (e.g. residuals). The two other transmissive units, the intermediate-sand and lower-sand units are confined by various aquitards to varying extent.

Groundwater Flow

To help evaluate and illustrate groundwater flow at the Allied OU, the following figures were prepared with significant input from the MDEQ:

- Three equipotential contour maps depicting the water table; one representing pre-IRM conditions (Figure 23 – September 1993), and two representing conditions after completion of the majority of the IRM (Figures 25 and 27). Figure 25 depicts the water table elevation in December 2001 during a period of relatively high water levels (a “wet season”), and Figure 27 depicts the water table in June 2003 during a period of relatively low water levels (a “dry season”).

- Three equipotential contour maps depicting the potentiometric surface at depth in the upper-sand unit (Figure 24, Figure 26, and Figure 28), drawn using data collected on the same dates as the three water-table figures described above. These maps were prepared to examine deeper portions of the upper-sand unit that may be hydraulically separated from the water table and confined by the peat and/or residuals aquitards.

- Flow nets along cross sections A-A’, B-B’, C-C’, F-F’, and G-G’ (Figure 29 through Figure 33), prepared with water-level data collected after completing the majority of the IRM.

- Groundwater hydrographs of selected monitoring points in key areas of the Allied OU (Appendix H).

The flow nets provide a conceptual interpretation of groundwater movement in these deeper units that is consistent with the available information and is sufficient for the purposes of this RI.

<u>Potentiometric Surface Maps</u>

To prepare the potentiometric surface maps (Figure 23 through Figure 28), BBL reviewed available water-level data (Section 3.2.5.4) and, with the approval of the MDEQ, selected the September 9, 1993, December 5, 2001, and June 19, 2003 data sets to produce the maps. It should be noted that water elevations from actively pumping extraction wells GWE-1A and GWE-4A may have resulted in skewed potentiometric surface water elevation data due to well loss. These data sets were selected for the following reasons:

- they were among the most complete data sets;

- they represent different seasons of the year, which is useful in identifying seasonal flow patterns;

- the June 19, 2003 data set was judged to be more representative of current pumping conditions of the IRM. At the time the other two data sets representative of current IRM pumping conditions (i.e., April and May, 2003) were collected, maintenance was being performed on several components of the groundwater-recovery system; and

- comparison among these dates may allow for an evaluation of the degree to which the IRM has affected groundwater flow patterns.

The water table beneath the Allied OU occurs principally in the upper-sand unit. As depicted on Figure 29, Figure 30, Figure 31, and Figure 33, the residuals are saturated due to placement below the water table in the Former Type III Landfill, the Bryant HRDL and FRDLs, and the Monarch HRDL. Water is also present in some of the gas vents installed in the partially-constructed cap over the Bryant HRDL and FRDLs (Table 3-5). This water may be interpreted to be hydraulically isolated from the underlying water table. This water may be from consolidation and dewatering of materials immediately below the gas-vent layer (particularly the saturated sediments dredged from the Former Bryant Mill Pond during the USEPA Removal Action), and/or precipitation during construction of the landfill cap. The low conductivity nature of the underlying residuals results in conditions in which groundwater collects in the gas vents above the upper aquifer and above unsaturated materials.

The maps depicting the water table before (Figure 23) and after (Figure 25 and Figure 27) completion of the majority of the IRM (referred to hereafter as the pre- and post-IRM water table maps) show a water table that generally represents a subdued replica of the Allied OU topography. As a result, shallow groundwater flows toward and discharges to Portage Creek. The general similarity of the three maps suggests that overall flow patterns have remained similar over the past 10 years and do not change dramatically seasonally. Some differences attributable to the IRM are evident between the pre- and post-IRM maps. These and several other useful observations made from the water-table maps are listed below:

- Shallow groundwater flow beneath the Western Disposal Area, Former Type III Landfill, and Bryant HRDL and FRDLs is semi-radial, moving outward away from a site high point beneath the Western Disposal Area toward Portage Creek. This high point is generally coincident with a site topographic high. Off-site to the west, the topography continues to rise (as shown on the graphic in Section 3.2.2) and it is likely the water table does as well, indicating that groundwater enters this portion of the OU from the west.

- Groundwater from beneath the Panelyte Landfill enters the Allied OU from the west before discharging to the creek. Some of the shallow groundwater beneath the Panelyte Landfill discharges to the Panelyte Marsh and flows overland to the creek.

- The configuration of the equipotential contours around FRDLs 1 and 2 suggest that groundwater discharges into the west end of FRDL 2 and flows radially out of the remainder of the FRDL, as well as out of FRDL 1. Groundwater flow patterns in this area are discussed in more detail later in this subsection.

- Differences between the pre- and post-IRM water table maps are generally minor; the patterns of flow do not seem to have changed substantially due to the sheetpile and groundwater-recovery system. This lack of major change in the water table is attributed to the permanent-sump component of the groundwater recovery system. Generally the system components mitigates groundwater mounding behind the sheetpile wall by effectively maintaining water-table elevations to near pre-IRM levels at many locations. Additional discussion regarding the evaluation of the recovery-system performance is presented in Appendix S.

- Portage Creek represents the surface water expression of the water table. As a result, shallow groundwater flow converges toward the creek. Water may flow out of the creek and onto its banks during storm events, when the stage of the creek rises rapidly. As evidenced by review of water elevation data for the creek and nearby shallow wells, such conditions at the Allied OU appear to be infrequent and short lived (see Table 3-4B). Near the end of storm events, the creek level would be expected to drop relatively rapidly, and the water that migrated onto the banks would return to the creek. At the extreme downstream end of the site near the Alcott Street dam, the creek is expected to routinely lose water during storm events. Although there are no piezometers in the area to provide the data necessary to confirm this theory, in such settings water would be expected to migrate out of the stream channel behind the dam and discharge to the creek channel on the downstream side.

Care is required when making direct comparisons between the water-table surfaces shown on the 1993, 2001, and 2003 figures (Figure 23, Figure 25, and Figure 27, respectively). This is because the data sets used to draw them are somewhat different, as a number of new wells were installed and old wells decommissioned at the OU over time. Comparison of the water table maps to the upper sand unit maps provides insight on the distribution of vertical gradients in these units. The pre-IRM (1993) water table and upper sand maps shows the following.

- Downward hydraulic gradients existed beneath the Monarch HRDL, Western Disposal Area, Bryant HRDL and FRDLs, and the Former Type III Landfill. The downward gradients beneath the HRDLs and FRDLs did not reverse to upward until very near Portage Creek.

- There is a transition from downward to upward hydraulic gradients near the northern end of the Former Type III Landfill (near monitoring well MW-5R). Upward hydraulic gradients are also present northward along the creek toward Alcott Street. In fact, several deeper wells across the site (e.g., MW-103, MW-104, MW-111, MW-204B) were occasionally observed to be flowing.

Flow Nets

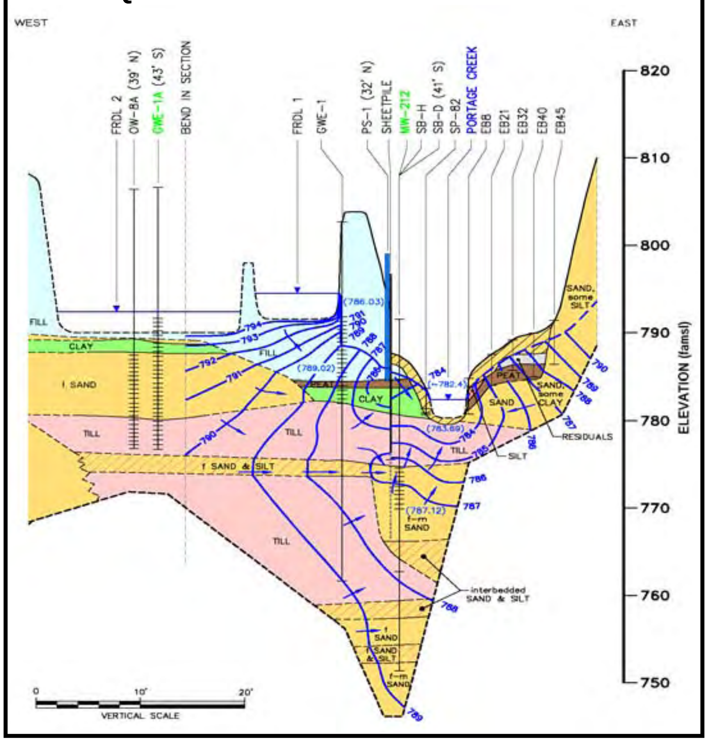
Flow nets are a useful tool to help interpret groundwater movement and how it changes, both with depth and with changes in geologic materials. The orientations of the vertical cross sections for which flow nets were prepared (i.e., cross sections A-A', B-B', C-C', F-F', and G-G' as presented in Figure 29, Figure 30, Figure 31, Figure 32, respectively) generally approximate groundwater flow directions inferred from the potentiometric contour maps. Due to the complex, heterogeneous nature of the subsurface, the flow nets should be considered qualitative in nature.

To prepare the flow nets (Figure 29 through Figure 33), BBL reviewed the available water-elevation data sets (Section 3.2.5.4) and, in consultation with the MDEQ, selected the June 19, 2003 data set. This set was chosen in large part because it represented the most current and most complete data set, and is representative of the recent pumping conditions of the IRM. Some of the wells that would have been useful in constructing the flow nets for the selected dates had been decommissioned. As such, older data were used to compliment the more recent data (where recent data were unavailable due to well abandonment) in order to develop site-wide groundwater flow maps. Generally, the wells decommissioned were in areas more distant from Portage Creek.

BBL reviewed the water-level data for the decommissioned wells and determined that select 1993 and 1994 data sets provided a reasonable approximation of what the hydraulic head conditions would likely have been at those wells on June 19, 2003. BBL's evaluation included such factors as seasonality and differences between water levels in wells for which both historic and June 2003 data were available. In addition, potential changes in hydraulic heads resulting from the IRM were also considered. As discussed later in this section, most such changes were limited to areas near the sheetpile and the nearby groundwater pumping centers. Fortunately, the decommissioned wells that were situated in the most strategic locations were far removed from the sheetpile and pumping areas or were screened beneath aquitards, where the effects of pumping from the groundwater recovery system are expected to be negligible.

Flow patterns depicted by the flow nets (Figure 29 through Figure 33) are typical of what would be expected given the site setting. Away from Portage Creek, there is a downward component to groundwater flow, particularly in the upper- and intermediate-sand units, for which hydraulic head data are most abundant. These are recharge areas – regions where groundwater in the Portage Creek drainage basin flows away from the water table. Though there is a downward component of flow, groundwater is also moving laterally toward Portage Creek – the discharge point of the drainage basin. Approaching the creek, the vertical component of flow reverses from downward to upward (as shown in well nest MW-219/229 in Figure 29), and groundwater moves toward the water table and ultimately discharges to Portage Creek. All flow nets depict that the hydraulic gradient is toward Portage Creek.

MDEQ's alternate version of F-F' flow net

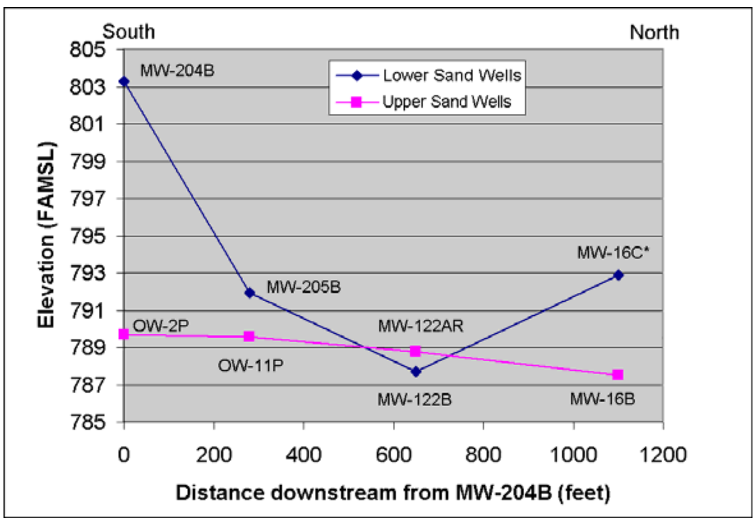


The flow nets illustrate several other important characteristics of groundwater flow at the site. Beneath most areas of the site, lateral flow in the transmissive hydrostratigraphic units is favored because these units have much higher horizontal conductivities and because the strength of horizontal gradients in the units tends to be greater than the strength of vertical gradients. An exception to this is near Portage Creek, where strong upward gradients exist. In aquitards, the flow nets suggest that vertical gradients tend to be greater than horizontal gradients, suggesting that flow directions in aquitards would have a greater vertical component than flow in transmissive units. These flow patterns are the result of the layered heterogeneity of the geology underlying the Allied OU. Such patterns are the norm in heterogeneous geologic systems and widely recognized in the literature (Freeze and Cherry, 1979; Fetter, 1988). Given their greater capacity to transmit water, it is clear that the majority of groundwater movement beneath the Allied OU occurs through the upper-, intermediate-, and lower-sand units. The Allied OU monitoring well network was designed to target these more transmissive units. This is evident on cross section D-D' (Figure 18), which is drawn along the sheetpile installed as part of the

IRM. In this area of the Allied OU, the monitoring wells were screened at key locations in the transmissive portions of the three stratigraphic units behind, at the base of, and below the sheetpile.

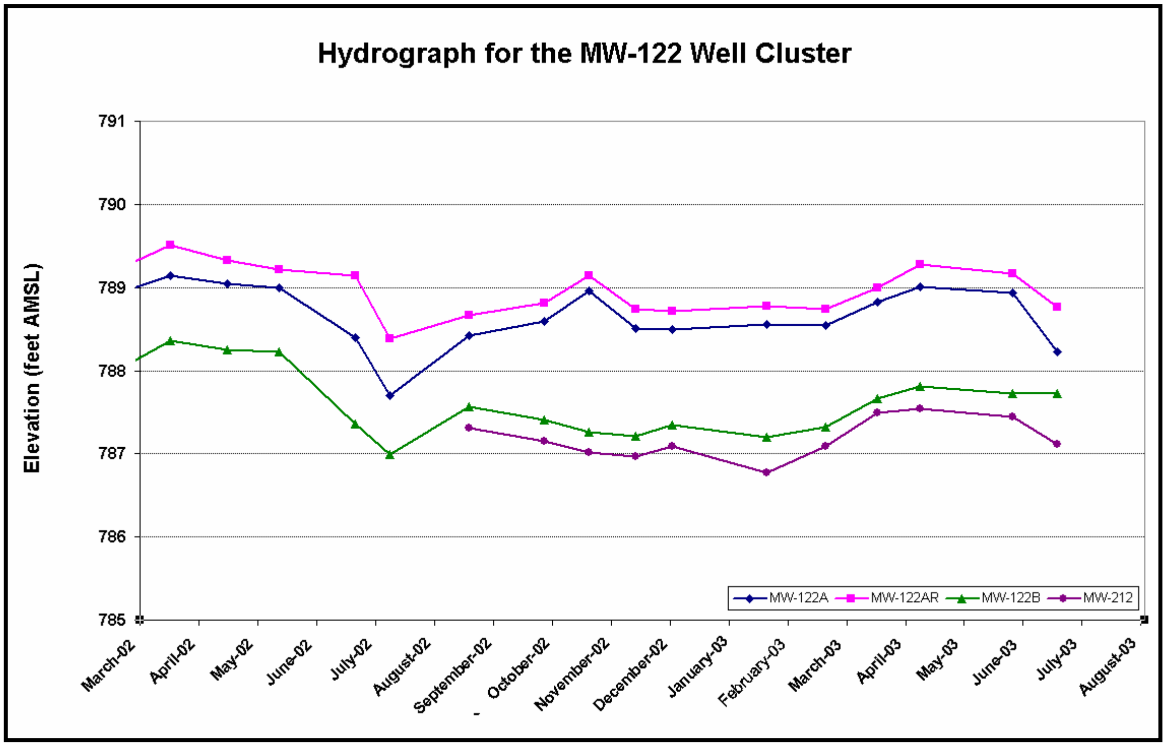
During the process of preparing flow nets and sending them to the MDEQ for preliminary review, the MDEQ developed an alternate version (above) of the geology shown on the flow net for cross section F-F' (Figure 32). The alternate version focused on the geology near the sheetpile wall, where the MDEQ used deep stratigraphic data from soil boring SB-D (located about 40 feet off section) to supplement data from MW-212 and SB-H to depict the geology in this area. This interpretation provides a scenario in which there is more potential for transport. The alternate F-F' cross section follows the same convention as used to develop the other cross-sections.

Comparison of water-level data for selected well pairs



Notes:
All data collected on June 19, 2003 except as noted.
* This well was decommissioned in 2000. Datum shown is an estimate based on all available water-level data for the well (Table 3-4B).

An important observation that is not apparent on the flow nets or potentiometric surface maps relates to water-level data for the lower-sand unit. As noted previously, few wells screen this unit, and those that do are generally aligned along Portage Creek. The above graph compares hydraulic head values for the lower- and upper-sand units at well clusters located along Portage Creek. For the upper-sand unit wells, which are screened at or near the water table, hydraulic head decreases upstream to downstream, as would be expected. The distribution of hydraulic head in the lower-sand unit wells is quite different, decreasing sharply from upstream to downstream, and rising again further downstream. The head loss between the lower-sand unit and converging hydraulic gradient toward the MW-122 cluster suggests that the integrity of the upper and lower aquitards may be compromised as shown in the above figure. Review of the flow net shown in Figure 32, which is aligned near the MW-122 well cluster, shows that groundwater beneath the peat in this area converges toward the intermediate-sand unit, which is screened by monitoring well MW-212. The hydrograph below shows that this condition has been consistent since well MW-212 was installed (the hydraulic head is always lowest at MW-212).



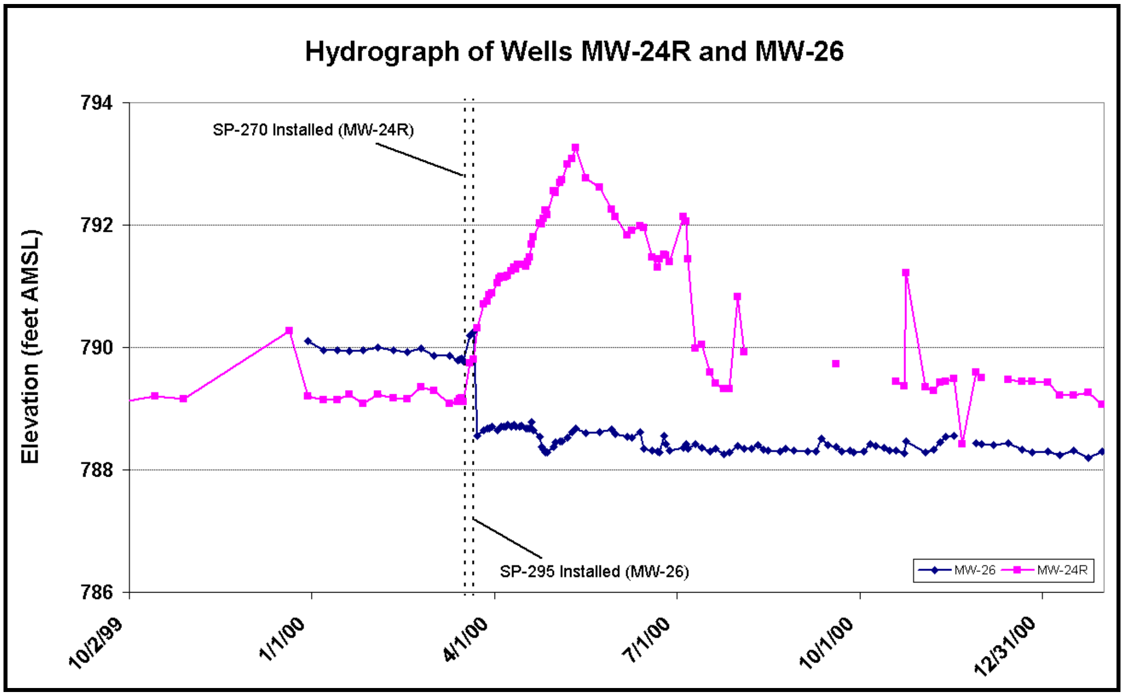
Effects of the IRM on Groundwater Flow

Construction of the IRM resulted in changes to groundwater flow patterns due to: 1) construction of the sealed-joint sheetpile wall, 2) operation of the groundwater recovery system, and 3) regrading and filling of FRDLs 1 and 2. Other IRM components that likely affected groundwater flow are the landfill cap (which was completed after the data analyzed in this report were collected). These effects are discussed below.

<u>Sheetpile</u>

The sealed-joint type sheetpile wall was installed in an attempt to create a hydraulic barrier to groundwater, impeding lateral flow to Portage Creek. The periodic leaking of groundwater though the sheetpile wall was observed in areas where the ground surface was higher on one side of the sheetpile than the other. Water samples collected in November 2003 from these periodically leaking joints were analyzed for PCBs. Sample results indicated the presence of PCBs ranging from 0.044 – 0.23 micrograms per liter (μg/L) (Table 4-4M). It is reasonable to assume that the sealed joint type sheet pile is not a perfect barrier to groundwater flow below the ground surface as well.

The most prominent initial hydrogeological effect of the sheetpile installation was groundwater mounding behind it. This phenomenon is evident in many of the hydrographs contained in Appendix H. Perhaps the best example is the hydrograph for monitoring wells MW-24R and MW-26, reproduced below. The water level in monitoring well MW-24R, which is located inside the sheetpile and mostly screened in the upper-sand unit, rose dramatically after installation of the sheetpile. The water level returned to its approximate pre-construction level several months later, after installation of the groundwater-recovery system. Converse conditions are represented at shallow well MW-26, located outside of the sheetpile and screened within the same upper sand unit. Water levels at this location dropped sharply in response to installation of the sheetpile, which apparently permanently reduced the supply of groundwater to the upper sand in this area.



The groundwater-recovery system does not collect all of the groundwater flow that was cut off by the sheetpile. The effectiveness of the groundwater-recovery system is further discussed in Appendix S. The degree to which the sheet pipe was effectively driven into the aquitard at all locations is not known. As a result, groundwater flow in the upper-sand and intermediate-sand units inside the sheetpile (where the sheetpile is not driven into the upper aquitard) moves downward, passes beneath the sheetpile, then upward to Portage Creek. This is evident on all five flow nets as shown in Figure 29 through Figure 33. In areas where the sheetpile is driven into or through the upper aquitard, groundwater flow to the creek within the upper and intermediate sand impeded by the sheetpile wall. This effect is evident in the upper sand on flow nets along cross sections C-C', F-F' and G-G' (Figure 31, Figure 32, and Figure 33, respectively). Some groundwater moves laterally around the southern (upstream) end of the sheetpile before discharging to Portage Creek. This is suggested on the water-table maps (Figure 25 and Figure 27) by the slight bend in the 796-feet equipotential contour at the upstream end of the sheetpile wall. Pumping at well GWE-1A serves to mitigate such movement of groundwater at the northern end of the sheetpile.

<u>Groundwater-Recovery System</u>

As previously explained, the groundwater-recovery system was installed primarily to mitigate the mounding of groundwater observed behind the sheetpile wall, with a goal of maintaining water levels within one foot of "pre-IRM" levels. As detailed in Appendix F, BBL originally planned to address groundwater mounding behind the sheetpile wall using a series of recovery wells. Data from pilot borings for those wells indicated that in some areas, pumping wells would not be the best method to address the mounding, primarily because the transmissivity of the upper-sand unit was lower than anticipated and would require many closely-spaced wells. This finding led to the current system, which combines a series of sumps and lateral drain lines above and into the peat, supplemented by pumping wells GWE-1A and GWE-4A installed in more transmissive regions of the upper-sand unit. The combined year flow (in million gallons) for this system is presented in Section 3.2.5.4. The reported Kalamazoo Water Reclamation Plant flows for years 2004, 2005, and 2006 (until September for 2006 data) are 7.74, 9.32, and 5.99 million gallons, respectively. Based on MDEQ's evaluation of the water level data from June 2004 to August 2006, provided in Appendix S, it appears that the goal of maintaining water levels within one foot of pre-IRM levels has been achieved with the exception of: MW-202B, MW-23R, MW-203B, MW-9, MW-201B, MW-22B, OW-3B, OW-6P, and MW-204B. The majority of these exceedances are situated near the southwest end of the sheetpile. The effects of the components of the groundwater-recovery system on groundwater flow are summarized below.

GWE-1A

Groundwater extraction well GWE-1A is installed in an area not addressed by the shallow-sump system. The primary purpose of the well is to maintain water levels to within the 1-feet criterion described in Appendix S. A secondary purpose is to mitigate movement of groundwater around the northern end of the sheetpile wall. The well screens the upper-sand unit (73% of the total screened interval) and the upper aquitard. The peat is absent at GWE-1A, as illustrated on Figure 22. The average pumping rate for GWE-1A is approximately 2.3 gallons per minute (gpm). This value represents the maximum average pumping rate that can be sustained by the well, as drawdown in the well is currently maximized. The influence of the well can be seen on Figure 25 through Figure 28. These figures show an elongated drawdown cone with its long axis oriented east-west. The elongation is the result of the well being located between two hydraulic boundaries, a no-flow boundary to the north (the sheetpile wall) and lateral flow to the south (FRDLs 1 and 2). If GWE-1A is operated at the appropriate pumping rate, flow around the end of the sheetpile can be controlled.

GWE-4A

Extraction well GWE-4A was installed, at the MDEQ's request, to maintain water levels within seasonal norms in this area and to help control potential migration of groundwater beneath the sheetpile wall where the till component of the upper aquitard was observed to pinch out (see cross section D-D', Figure 18). Unlike conditions at GWE-1A, the peat is present at GWE-4A, as is the permanent-sump component of the groundwater recovery system (installed above the peat). GWE-4A screens the native-sand portion of the upper-sand unit beneath the peat, and is currently pumped at an average rate of 8 gpm. Prior to July 2002, GWE-4A was pumped at an average rate of 13 gpm, but the well did not need to be pumped at this rate to keep groundwater levels within target elevations. The hydrographs presented in Appendix H indicate that pumping at GWE-4A influences water levels at the following wells and piezometers:

- MW-22AR, located approximately 65 feet to the east, which screens the upper-sand unit (fill material) above the peat;

- MW-10, located approximately 60 feet to the east, which screens the upper-sand unit below the peat;

- OW-12A, located approximately 68 feet to the east, which screens the upper-sand unit below the peat;

- OW-16P, located approximately 154 feet to the east, which screens the upper-sand unit above the peat;

- OW-13A, located approximately 82 feet to the west, which screens the upper-sand unit below the peat; and

- OW-4AR, located approximately 215 feet to the west, which screens the upper-sand unit below the peat.

The drawdown influence of this pumping well demonstrates that the peat will not be an effective separation layer between the upper and lower sands. The influence of pumping at GWE-4A can be seen in plan view on Figure 25 through Figure 28. The pumping influence is most pronounced on Figure 26 and Figure 28, which depict the potentiometric surface at depth in the upper-sand unit (where GWE-4A is screened). Drawdown related to the current pumping rate (illustrated on Figure 28) extends approximately 170 feet and 220 feet to the east and west of GWE-4A, respectively. The reason for the uneven distribution of drawdown along the sheetpile can be seen on cross section D-D' (Figure 18). The native sand deposit into which the screen for

GWE-4A was installed pinches out about 170 feet toward the east, and toward the west about 150 feet from the pumping well. The drawdown cone associated with GWE-4A on Figure 26 is larger than that on Figure 28 due to the higher pumping rate (13 gpm during December 2001 vs. 8 gpm during June 2003). The extent of pumping influence on the water table can be seen on Figures 25 and Figure 27. Comparison of the piezometric surfaces in these figures indicates the influence of pumping at GWE-4A to be much greater in the upper sand unit below the peat. The effect of pumping at GWE-4A above the peat is evidenced by drawdown observed at wells/piezometers MW-22AR and OW-16P. Sump PS-6 and piezometer OW-13P (both screened above the peat) appear to have been drawn dry as a result of pumping at GWE-4A. The diminished effect of pumping above the peat in that area reduces, but does not prevent, groundwater from migrating across it. Pumping at GWE-4A increases the downward hydraulic gradient, and in turn, the flow of groundwater across the peat.

The above observations indicate there to be overlapping influence on groundwater recovery from the sump-trench system and GWE-4A. It appears that the presence of the peat and other factors (e.g. well construction, hydraulic permeability, of the various layers, pumping rate etc.) limits the ability of GWE-4A to lower the water table.

Permanent Sump System

The effect of the permanent sump system on groundwater flow is straightforward. The system maintains water levels behind the sheetpile at roughly what they were before the sheetpile was installed. The only exception is at piezometer OW-6P (screened within fill above the peat near the upstream end of the sheetpile), where water levels have occasionally exceeded the criterion. Cross section E-E' (Figure 19) and the water-table contour maps (Figures 25 and 27) illustrates the interpretation that groundwater at OW-6P may be collected by permanent sump PS-6. However the groundwater in the area of OW-6P most likely moves around and beneath the sheetpile wall before discharging into Portage Creek.

<u>Bryant FRDLs 1 and 2</u>

Bryant FRDLs 1 and 2 predate the IRM and influenced local groundwater flow patterns before the IRM was constructed; however, these FRDLs were modified by the IRM and are not expected to continue to influence groundwater flow. Historically, FRDLs 1 and 2 acted as a source of recharge to the groundwater flow system, creating a mound in the water table. The effects of the FRDLs prior to the IRM cannot be quantified because water-level data were not collected in this area. It is reasonable to infer that they allowed the infiltration of water, as they were unlined and were built-up above the former floodplain of Portage Creek. This leakage may initially have historically occurred through the bottoms of the FRDL but as thick deposits of residuals accumulated within the FRDLs over a period of years, the primary pathway of water likely changed to lateral movement through the berms that form their sides. Pre-IRM water levels in monitoring wells MW-122A and MW-122AR (see the hydrograph entitled "MW-122 Well Cluster" in Appendix H), which are installed in one of these berms, appear to be influenced by the FRDLs. As shown on the hydrograph, water levels in these wells fluctuated considerably, in some cases by as much as 5 to 7 feet. The background well shows no such fluctuations. The most plausible explanation for these fluctuations is hydraulic influence by the FRDLs, which received surface runoff.

During construction of the IRM in the summer of 2000, accumulated materials at the bottom of the FRDLs (including residuals) were removed and stormwater from a portion of the new cap was routed to the sedimentation basin. This may have increased the hydraulic communication between the FRDLs and the underlying upper-sand unit. At the same time, staff gages were installed in the FRDLs and periodic monitoring of the level of water in them began. From the MW-122 Well Cluster hydrograph (Appendix H), it appears clear that fluctuations in the FRDL water levels result in corresponding fluctuations in wells MW-122A and MW-122AR, strongly suggesting a hydraulic connection. The hydraulic connection between surface water held in the FRDLs and the local groundwater system was confirmed by a correlation analysis of water levels in FRDL 2 and several nearby monitoring wells (Appendix H). The analysis showed that a statistically significant relationship exists between surface water and groundwater elevations, with greater correlations associated with precipitation events. The correlations are less significant during periods between precipitation events, as the diminished flow of surface water into the groundwater system during these periods has a correspondingly smaller effect relative to other factors such as upgradient recharge and barometric pressure. Regardless, the hydraulic connection is demonstrated even in the absence of precipitation.

As previously discussed, residuals were removed from the bottom of FRDL 2 in preparation for capping in 2000, thereby increasing the hydraulic connection to the underlying sand unit. In 2003, the settling basin was completed with a double liner, and FRDL 1 was backfilled and capped as part of the IRM. These actions will mitigate the migration of stormwater and gas vent water collected in FRDL 2 into the underlying deposits.

<u>Landfill Cap</u>

As described in Section 1.2.3.2, the majority of the Bryant HRDLs and FRDLs were capped during 2000. The capping activities associated with the IRM are now completed. Capping reduces the amount of recharge to the groundwater table over the area covered by the cap and should result in a corresponding reduction of leachate production over time. Secondary consolidation and dewatering of the residuals in the Bryant HRDL and FRDLs is expected to continue for a long period of time. Therefore, while there are expected to be short-term improvements in groundwater quality due to a reduced influence of leachate as a result of construction of the landfill cap, the complete benefits may be fully realized only after a period of years.

3.3 Site Wetlands Assessment

3.3.1 1993 Wetlands Assessment

As discussed in Section 2.7.1, wetlands at the Allied OU were characterized in 1993 based on vegetation, hydrology, and soil type following USACE (USACE, 1987) guidance. Wetland areas were identified within the Former Bryant Mill Pond, a small area of the Portage Creek floodplain adjacent to the Bryant HRDL, and small inundated areas within the Bryant HRDL. The Former Bryant Mill Pond and Bryant HRDL areas consisted of emergent marsh vegetation, while the floodplain area consisted of scrub-shrub vegetation.

The small wetland areas observed in the man-made Bryant HRDL were transient features that evidently developed after discontinued use of the lagoon. These areas were backfilled with soil and residuals excavated from the Former Bryant Mill Pond during the USEPA Removal Action. Several wetland areas identified on NWI maps were not found at the OU during the wetland assessment in 1993 due either to physical alteration or incorrect identification of the areas as wetlands during the NWI interpretation.

Further details regarding historical descriptions of the wetlands and habitat are presented in Sections 2.6 and 2.7 of the *DCS* (BBEPC, 1992), and Sections 2.3 and 3.3 of *Technical Memorandum 11* (BBL, 2000a).

3.3.2 2001 Wetlands Delineation

MDEQ conducted a wetland delineation at the Allied OU in 2001 to evaluate the impact of the USEPA Removal Action. After excavating the entire wetland area of the Former Bryant Mill Pond, the USEPA reestablished vegetation by applying a seed mix specifically designed for wetlands, and by planting cattails, willows, and dogwoods in selected areas (Weston, 2000). The wetlands identified during the MDEQ's 2001 delineation effort (depicted on Figure 34) consisted largely of wetland areas that were re-established by the USEPA.

The MDEQ identified approximately 15.2 acres of emergent vegetation wetlands located throughout the Former Bryant Mill Pond, and 2.5 acres of palustrine scrub-shrub wetlands in the Portage Creek floodplain, with smaller areas in the Bryant FRDLs and Western Disposal Area. In addition to the areas identified by the MDEQ, a small area (less than 1 acre) of emergent vegetation wetland not shown on Figure 34 is located in the Panelyte Marsh north of the Western Disposal Area.

The existence of wetlands in the Former Bryant Mill Pond and Portage Creek floodplain is attributable, at least in part, to human alterations of the land. Although the Alcott Street Dam was opened and the water level was drawn down in 1976, the dam nonetheless continues to impound surface water and sediment within Portage Creek, raising the water table and inundating soils that would not otherwise be saturated. Although the sheetpile installed for the IRM at the Bryant HRDL and FRDLs may be expected to alter groundwater flow paths, it does not appear to have affected the extent or viability of the adjacent wetlands, which have thrived since being re-established by the USEPA.

Wetland restoration conducted by the USEPA after the Removal Action is discussed in Section 4.11 of the *Final Report* (Weston, 2000). Additional information regarding the methods and findings of the MDEQ's 2001 wetland delineation is presented in the *Kalamazoo River and Portage Creek Wetland Delineation Study* (CDM, 2002a).

4. Nature and Extent of Contamination

This section describes the nature and extent of contamination in environmental media at the Allied OU and considers all of the data collected at the site (see Location of Analytical Data box presented below). Discussions later in this section will describe how the data are included or excluded in the determining of the nature and extent of impact at the site. Detailed discussions regarding earlier investigations of various media at the OU are presented in *Technical Memorandum 4* (BBL, 1994a) (air), *Technical Memorandum 7* (BBL, 1997c) (residuals, soil, groundwater, sediment), *Addendum to Technical Memorandum 7* (BBL, 1999) (groundwater), and *Technical Memorandum 11* (BBL, 2000a) (surface water and biota). Although these memoranda are useful in developing an understanding of some aspects of Portage Creek and the other study areas, as well as establishing the historical context of environmental issues, they do not provide a complete description of current conditions at the site. As discussed previously, the above technical memoranda illustrate conditions prior to the Removal Action and IRM, which significantly modified the Former Bryant Mill Pond and Bryant HRDL and FRDL areas.

Development of Screening Criteria

For the purposes of preparing the FS, the current and future land-use of the Allied OU areas should be considered in the determination of whether an area poses an actual or potential risk to human health. Areas that will be restricted to industrial uses are evaluated with respect to the State's health-based soil criteria for industrial/commercial land use. Areas zoned residential are evaluated with respect to the State's health-based soil criteria for residential land use.

Risks to ecological receptors are evaluated with respect to ranges established in the Baseline Ecological Risk Assessment (BERA) for the protection of ecological receptors, for all areas that the criteria apply. Additionally, in order to aid in evaluating the nature and extent of the groundwater contamination at the site, the available data for all contaminants are compared to the State's lowest generic groundwater criterion. The surface water data for the site will be compared to State water quality standards. Biota samples, where available, are compared to MDCH standards.

It should be noted that the State generic criteria for soil do not differentiate between soil and sediment. However, the PCB criteria developed in the site specific BERA and Human Health Risk Assessment (HHRA) consider the differences between the soil and sediment matrices and as such, have developed criteria for both. Future application of the soil/sediment criteria will be dependent on the inundation periods. These inundated areas will be further evaluated during future remedial decision making at the operable unit which will include the development of a scientifically valid indicator of inundation period in order to determine where a sediment-to-fish-to-consumer exposure pathway at the Allied OU areas presents an unacceptable risk to consumers (human or ecological) of fish. If, after applying the inundation period indicator to an area, a sediment-to-fish-to-consumer exposure pathway is determined to present an unacceptable risk to consumers of fish, then the more conservative aquatic sediment criteria established in the HHRA will be applied to protect people who consume fish. The aquatic sediment criteria established in the HHRA range from 0.04 mg/kg to 0.51 mg/kg PCB; however, because MDEQ has a detection limit of 0.33 mg/kg for PCBs, the cleanup criteria protective for people consuming fish defaults to 0.33 mg/kg. The sediment cleanup criteria of 0.33 mg/kg PCB is also protective of fish-eating animals. If, after applying the inundation period indicator to a wetland area a sediment-to-fish-to-consumer exposure pathway is determined not to present an unacceptable risk to consumers of fish, then a cleanup level that is within the acceptable no observed adverse effects (NOAEL)/ lowest observed adverse effects (LOAEL) range of 6.5 mg/kg to 8.1 mg/kg PCB will be applied to these areas to protect terrestrial ecological receptors.

As PCBs have been identified as the main contaminants of concern (COC) at this and other operable units within the Kalamazoo River Superfund Site, the potentially applicable PCB criteria for the various media are listed below. (Note: The maximum concentrations in the following tables reflect historic results and may not be representative of current conditions.) The potentially applicable soil and groundwater criteria for the various TAL/TCL contaminants will be identified later in the report.

Applicable PCB Screening Criteria for Soil

Maximum RI PCB Concentration (mg/kg)	Part 201 Generic Commercial II & Industrial Criteria	Part 201 Residential Land Use Criteria	Terrestrial Soil Criteria Protective of the Robin (NOAEL/ LOAEL) in Ecological Risk Assessment
Surface: 110 mg/kg Subsurface: 2,500 mg/kg	16 mg/kg	4 mg/kg	6.5 mg/kg / 8.1 mg/kg

Applicable PCB Screening Criteria for Sediment

Maximum RI PCB Concentration (mg/kg)	Angler Risk Based Criteria	Ecological/Mink	MDEQ Default Detection Limit
Surface 12.3 mg/kg Subsurface 16.0 mg/kg	0.04 mg/kg to 0.51 mg/kg	0.5 mg/kg to 0.6 mg/kg	0.33 mg/kg

Applicable PCB Screening Criteria for Groundwater

Maximum RI PCB Concentration (μg/l)	Part 201 Generic Drinking Water Criteria	Part 201 Groundwater Surface Water Interface Criteria	Part 201 Groundwater Volatilization Inhalation Criteria	Part 201 Groundwater Contact Criteria
4.9 μg/l	0.5 μg/l	0.2 μg/l	45 μg/l	3.3 μg/l

Applicable PCB Screening Criteria for Surface Water

Maximum RI PCB Concentration (μg/L)	Michigan Human Health Water Quality Criteria	Michigan Wildlife Water Quality Criteria	NOEL/LOEL Surface water to Fish Threshold
1.75 μg/l	0.000026 μg/l	0.00012 μg/l	0.0016 - 0.00197 μg/l l

Applicable PCB Screening Criteria in Fish Tissue

Maximum RI PCB Concentration in Fish (mg/kg) – Adult Carp	MDCH General Population No-Consumption	MDCH One Meal/Month (Women & Children)	MDCH One Meal/Week (Women & Children)
12.0 mg/kg	2 mg/kg	0.2 mg/kg	0.05 mg/kg

Location of Analytical Data

Since the RI activities began in 1993, the database for the Allied OU is extensive. To facilitate review of the data, summary tables presenting the frequency of detection and range of detected concentrations are included in the tables for this section of the report. The results for all individual samples collected for chemical analysis are presented in expanded tables organized by study area that are included on the enclosed DVD (DVD). These expanded tables are identified by a "CD" suffix in the table number [e.g., Table 4-2A(CD) through Table 4-2M(CD)]. On the "CD" tables, those data that BBL characterized as historical conditions are shaded to visually differentiate them from data that BBL interpreted to represent existing conditions, allowing easier recognition of data that characterize the current nature and extent of contamination. For example, sediment sample data collected from the Former Bryant Mill Pond prior to the Removal Action and IRM are shaded in the "CD" tables to indicate that these data represent historical conditions. The corresponding tables in this section present summaries of detected concentrations and exceedances of screening criteria for each study area.

While the assessment of nature and extent is based primarily on the data that were collected by MHLLC, this report also makes extensive use of data for split samples collected by the MDEQ. The frequency of detection and range of detected concentrations for these split samples are also summarized in the tables for this section. Individual sample results for MDEQ and USEPA data (post-excavation data from the Removal Action) are presented in Appendix MDEQ - B and Appendix USEPA, respectively.

The assessment of nature and extent is based on the data collected by BBL, MDEQ and USEPA and are presented in the Section 4 tables during the investigations described in Section 2.

Overview of Nature and Extent of Contamination

For purposes of considering the nature and extent of contamination at the operable unit, certain assumptions in regard to the conceptual site model should be understood. One such assumption is that the various waste disposal areas present at the site represent an unacceptable risk and will be addressed during the remedial action phase of the project (presumptive remedy actions such as consolidation and capping as selected at the other operable units on the river). These assumptions are based on knowledge of the types of waste disposed in these areas (principally contaminated residuals) and an understanding of the nature of these materials from work at other operable units. As the contaminated nature of these materials is well understood, it was decided that extensive investigation of the waste disposal areas at the site was not required.

4.1 Air Investigation

During the 1993 air investigation, ambient air samples were collected at seven sampling locations – five around the perimeter of the OU and two in Battle Creek – and evaluated for the presence of vapor-phase and particulate-phase PCBs. High-volume polyurethane foam (PUF) cartridge samplers were used following USEPA Compendium Method TO-4 (USEPA, 1988). The method is summarized in the *FSP* (BBEPC, 1993a). The five air sampling locations at the OU (AP-1 through AP-5) are shown on Figure 4. AP-2 and AP-3 were located next to each other and served as duplicate samples for quality assurance/quality control purposes. The results of the air investigation are discussed in Section 3 of *Technical Memorandum 4* (BBL, 1994a). Table 2-1 presents a summary of the air samples submitted for chemical analysis during the RI. A summary of the Allied Meteorological Station hourly average data are presented in Table 3-1. The frequency and range of detected vapor-phase PCB concentrations for each sampling location are summarized for reference in Table 4-1. PCBs were not detected in any of the airborne particulate-phase samples collected at the Allied OU, and are therefore, not tabulated in this report.

The mean vapor-phase PCB measurements at the OU perimeter sampling locations ranged from 0.00090 micrograms per cubic meter ($\mu g/m^3$) at sampler AP-2 to 0.0064 $\mu g/m^3$ at sampler AP-4 for the 15 days sampled during the study period, June 6 through August 29, 1993. Local background concentrations were evaluated by reviewing the measurements of the hourly average wind direction during each sampling event, and identifying the samplers that were not downwind of the OU (AP-1 for 7 of the 15 days, AP-5 for 5 of the 15 days sampled, and AP-2/3 for 1 of the 15 days sampled) during any hour interval of the sample event. The resulting mean local background level was estimated to be 0.00094 $\mu g/m^3$. In comparison, the mean background of the combined concentrations at the two samplers in Battle Creek, a similar but smaller urban environment in Michigan, was 0.00034 $\mu g/m^3$. The results indicate that the mean PCB concentrations at all five air sampling locations around the perimeter of the Allied OU were higher than the means of the Battle Creek observations. In addition, four of the five air sampling locations were above the mean local background concentration determined by wind direction. AP-2 with a reported mean of 0.0009 $\mu g/m^3$ was essentially equal to the mean local background concentration. However, none of the mean concentrations exceeded the secondary risk screening levels under Michigan Air Toxic regulations.

For purposes of characterizing exposure and risk, the most appropriate point of comparison is the annual average PCB concentration in air. The MDEQ has developed health-based Secondary Risk Screening Levels (SRSLs) for air contaminants with carcinogenic (i.e., cancer-causing) effects. Air Toxics are assessed according to the risk assessment procedures in R 336.1229(1). The SRSL is defined as the concentration of a possible, probable, or known human carcinogen in ambient air which has been calculated for regulatory purposes, expected to produce an estimated increase in the upper-bound lifetime cancer risk of 1 in 100,000. For PCB, the SRSL is currently 0.02 $\mu g/m^3$. This threshold was not exceeded for the 72 results reported.

As described in *Technical Memorandum 4* (BBL, 1994a), based on case studies in the literature, annual average concentrations at the Allied OU can be assumed to be lower than the summer time means measured during the Air Investigation. Additional air quality data are presented in the USACE Allied Paper/Portage Creek/Kalamazoo River Superfund Site Final Report (USACE, 2000).

Any future review of the 1993 air sample analytical results to potentially applicable criteria must be conducted with the understanding that these samples were collected before completion of the Removal Action and IRM, which significantly reduced the area where residuals were exposed at the ground surface. These actions are expected to have decreased PCB concentrations in the air at the Allied OU. Determination of the applicability of cleanup criteria for soils and other environmental media at the Allied OU will be made by the USEPA, in consultation with the MDEQ, during review of Applicable or Relevant and Appropriate Requirements (ARARs) in the FS.

4.2 Soils Investigation

The soils investigation included the collection and chemical analysis of 327 samples of soils at 125 locations throughout the Allied OU (see Figure 5 and Figure 6 for locations) between 1991 and 2003. Soil samples, for purposes of this RI, are defined as any solid matrix (soil or residuals) that was collected from an area 1) outside of the Portage Creek channel or other surface water body and 2) outside of an area adjacent to Portage Creek that may be inundated during a high flow event. As the area of inundation has not yet been defined for the OU, some samples currently identified as sediment may be reclassified as soil in the future and vice versa. The RI-related efforts carried out since 1993 were designed to chemically and/or physically characterize the soils in each of the study areas at the site. The soil samples collected for the RI are supplemented by “confirmation” soil samples collected to verify the effectiveness of excavations conducted during the IRM. In this report, soil and sediment are divided into surface and sub-surface. Samples were classified at the time they were collected. Since that time, some samples may have been covered with more than 2 feet of fill. This is particularly the case in the areas that have been capped as well as the areas in the former Bryant Mill Pond. Table 2-2 presents a summary of the soil samples submitted for chemical analysis during the RI. Table 4-2A through Table 4-2H summarizes the frequency of detection and range of detected concentrations for the detected constituents in soil samples that represent current conditions. The analytical results for split samples collected by the MDEQ are similarly summarized in Tables 4-2A through Table 4-2H. The data for individual soil samples collected by MHLLC for the RI are presented in Tables 4-2A(CD) through 4-2M(CD). MDEQ and USEPA data are presented in Appendix MDEQ - B and Appendix USEPA, respectively.

The Removal Action and IRM included the excavation of residuals and PCB-containing soils from the Former Bryant Mill Pond and the banks of Portage Creek. Those locations that were sampled before but removed during the IRM activities are referred to as excavated data in this report. Although the excavated analytical data are indicative of the contaminants and their respective concentration that was excavated, the information may be indicative of the adjacent areas that were not excavated (i.e., contaminants and their concentrations at sampling locations BMP-2, BMP-12, MA-2, MA-3, MA-5, BLHB-1, RP-5, BMP-9, BMSS-3, and BMSS-4). The results associated with the excavated samples are shaded in gray on the CD series tables.

The analytical data obtained in early phases of the soils investigation are discussed in previously submitted reports. The concentrations and distribution of constituents detected in soils and residuals samples collected on MHLLC property near adjacent residences in 1991 are discussed in Section 4.2.1.2 of the *DCS* (BBEPC, 1992). The analytical results of soils and residuals samples collected between 1993 and 1997 are discussed in detail in Section 3.3 of *Technical Memorandum 7* (BBL, 1997c) and in correspondence to the MDEQ (Cowin, 1998). The data collected at the OU since 1993 for TCL constituents, TAL constituents, PCDDs/PCDFs, and PCBs are summarized in this section of the report. The analytical results for samples collected between 1999 and 2003 are included in Appendix J.

Screening Criteria

For the purposes of developing COCs for the Allied OU, applicable media are compared to the MDEQ generic criteria for soils. As an initial screening, all laboratory results were compared to Table 2 of RRD Operational Memorandum No. 1, Part 201Generic Cleanup Criteria and Screening Levels (12/23/06) of Part 201 (MDEQ, 2004).

The MDEQ has, however, derived site-specific risk-based criteria of PCBs designed to be protective of human and ecological receptors potentially exposed to site soils along the Kalamazoo River Superfund Site (CDM, 2003a and b). Site specific terrestrial ecological and recreation user criteria, have been developed for the site which are 6.5 mg PCB/kg and 23 mg PCB/kg, respectively. However, the residential criteria of 4 mg PCB/kg was used as the screening threshold for PCBs in soil in this report.

Determination of the applicability of cleanup criteria for soils and other environmental media at the Allied OU will be made by the USEPA, in consultation with the MDEQ, during review of ARARs in an FS to be written in the schedule defined by the USEPA.

4.2.1 TCL Compounds in Soil Samples

Some of the samples collected as part of the RI efforts carried out between 1993 and 2003 were analyzed for the CLP TCL compounds. These samples were either identified in the RI/FFS Work Plan (BBEPC, 1993a) or selected in the field by the MDEQ. The TCL includes a variety of PCBs, PCDDs/PCDFs, VOCs, SVOCs, and pesticides. The results of soil sample analyses for these compounds are presented below and these data are discussed for the various areas of the site when applicable.

Samples were collected during the soils investigation to characterize the nature and extent of PCBs present at the site. Surface and subsurface samples of soils were collected during several phases of investigation conducted between 1993 and 2003. In addition, soil confirmation samples were usually collected to verify PCB concentrations along excavation floors and sidewalls upon completion of excavation activities conducted for the IRM.

The boring logs, analytical data, and visual observations generated during these surface and subsurface soils and residuals sampling efforts were used along with USEPA's excavation confirmation soil sample data collected during the Removal Action (Weston, 2000) to prepare two maps. Figure 35A depicts the delineated current extent of surficial (0 to 2 ft below ground surface [bgs]) PCB-containing soils and/or residuals at the Allied OU. Figure 35B shows the delineated current extent of PCB-containing soils and/or residuals at any depth. For the purpose of developing conservative representations of site conditions, if there was either visual evidence of residuals or analytical data indicating the presence of PCBs at any concentration at a sampling location, that location and the surrounding area were identified as containing PCBs. Landforms (e.g., drainage ways) and historical land uses were taken into account when approximating the extent of PCB-containing soils and residuals. Where the extent of PCB-containing soils was obscured by modifications to the land (e.g., properties east of Portage Creek), the depicted area was conservatively shown to extend to the nearest known uncontaminated sampling locations. These geographic divisions are based primarily on ownership and historic land use, and include the Former Operational Areas (consisting of the Former Bryant HRDLs and FRDLs, Monarch HRDL, Western Disposal Area, Former Type III Landfill, and limited areas near Alcott Street), the Former Bryant Mill Pond (area defined by USEPA Removal Action),and the Residential/Commercial properties (consisting of the various commercial and residential properties to the east of portage creek and the Former Panelyte and Conrail Properties on the western portion of the site).

4.2.1.1 PCBs in Soil Samples

Surface Soils and Residuals

Eighty-nine samples of surface soils (samples collected at depths less than two feet below grade) were collected and analyzed for PCBs. Surface soils samples analyzed for PCBs were collected in the Former Operational Areas, the Former Bryant Mill Pond, and Residential/Commercial areas. The data suggests that the majority of samples had concentrations of PCBs below the screening criteria and that the locations of samples which exceed the screening criteria are limited to the Former Operational Areas. The majority of these PCB exceedances occurred within 0.5 feet of the surface.

Soils with visual indicators of residual impact can be expected to have PCB concentrations similar to those identified in the Bryant Mill Pond. PCB concentrations of material deposited as Bryant Mill Pond sediment are generally characterized by borings BMP-1, -2, -3, -4, -8, -10, -11, and -12 (borings with visual indicators of residuals), which indicate PCB concentrations range from 1.7 to 510 mg/kg. It should be noted that sample locations submitted to the lab for PCB analysis for the Residential/Commercial areas were selected from clean/unimpacted areas intended to define the extent of PCB impact. Samples with visual indicators of residual impact were not submitted for laboratory analysis, therefore the data in these areas are biased low. PCB impact above the screening criteria is assumed to extend out to the clean boring locations The delineated extent of PCB-containing surface soils and residuals is shown on Figure 35A (constructed using both the visual presence of residuals and analytical data from boring locations), which depicts that PCBs are present in all areas of the site. This PCB impact is assumed to be present at concentrations above the screening criteria.

The analytical results of these samples are presented in Table 4-2J(CD). The frequency of detection and range of detected concentrations of total PCBs in samples that have not been excavated are presented in Table 4-2A. Table 4-2B presents the location and concentrations of each PCB exceedance. The location of these samples with PCB concentrations exceeding the screening criteria are presented in Figure 4-2A. Total PCB concentrations in surface soil samples at the site ranged from non-detect to 110 mg/kg.

Subsurface Soils

There were 234 samples of subsurface soil samples (samples collected at depths greater than 2 feet below grade) collected and analyzed for PCBs throughout the site. Subsurface soil samples analyzed for PCBs were collected in the Former Operational Areas, the Former Bryant Mill Pond, and Residential/Commercial Areas. The data indicates nearly 44 percent of the samples collected at the site had PCB concentrations above the screening criteria. There were 167 subsurface samples collected within the Former Operational Areas of which nearly 80 percent indicated the presence of PCBs. The locations of samples that exceed the screening criteria are limited to the Former Operational Areas with the exception of one sample in the Residential/Commercial area to the east of Portage Creek (Stryker Property). However, sample locations submitted to the lab for PCB analysis from the Residential/Commercial areas were preferentially selected from clean/unimpacted areas intended to define the extent of PCB impact. Samples with visual indicators of residual impact were not submitted for laboratory analysis, therefore the data in these areas are biased low. As discussed under Surface Soils and Residuals, material deposited as Bryant Mill Pond sediment are generally characterized as containing PCBs with concentrations ranging from 1.7 to 510 mg/kg.

PCB impact above the screening criteria is assumed to extend out to the clean boring locations. The delineated extent of PCB-containing subsurface soils and residuals is shown on Figure 35B (constructed using both the visual presence of residuals and analytical data from boring locations), which depicts that PCBs are present in all areas of the site. Where residuals are located at the site it is assumed that they contain PCBs at concentrations above the screening criteria.

The analytical results of these samples are presented in Table 4-2K(CD). The locations of 40 of the subsurface soil samples, shaded in Table 4-2K(CD), were removed during the Removal Action or IRM. The frequency of detection and range of detected concentrations of total PCBs are presented in Table 4-2C. The samples that exceeded the screening criteria are presented in Table 4-2D and their corresponding locations are presented in Figure 4-2B. Total PCB concentrations in subsurface soil samples ranged from non-detect to 2,500 mg/kg.

4.2.1.2 PCDDs/PCDFs in Surface Soil Samples

For the entire site, eight samples of surface soils were collected and analyzed from seven locations for PCDDs/PCDFs. No samples collected at the site and classified as subsurface soil were analyzed for the presence of PCDDs/PCDFs. This limited set of surface soil samples analyzed for PCDDs/PCDFs were collected in the Former Operational Areas only. The single location that exceeded the screening criteria is found in the

Former Monarch HRDL. The data set is limited as we understand that these compounds may be associated with areas of the site where PCB impact is present.

The analytical results of these samples are presented in Table 4-2I(CD). The frequency of detection and range of detected concentrations of PCDDs/PCDFs summed by the toxicity equivalence factors (TEFs) for each of the PCDDs/PCDFs relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin are presented in Table 4-2E. One or more PCDDs/PCDFs were detected in the 8 samples. Of the PCDDs/PCDFs at the time of the testing, 15 were detected in the surface soils samples but was only exceeded at one location. The sample location that exceeded the screening criteria is presented in Figure 4-2C.

4.2.1.3 TCL VOCs in Soil Samples

Surface Soils and Residuals

For the entire site, three samples of surface soils were collected and analyzed from three locations for TCL VOCs. Of the surface soil samples analyzed for VOCs, one was collected from the Former Operational Areas and two were collected in the Residential/Commercial Areas (specifically in the area of the Clay Seam). The concentrations of VOCs did not exceed any of the screening criteria for the respective compounds. Although the surface data set are limited, when considered in conjunction with the subsurface data set, VOC compounds do not appear to be associated with the contaminant impact identified at the site.

The analytical results of these surface soil samples are presented in Table 4-2A(CD). The frequency of detection and range of detected concentrations of VOCs are presented in Table 4-2E. One or more VOCs were detected in two samples. Of the VOCs on the TCL at the time of the testing, two were detected in the surface soil samples (listed in order of decreasing frequency): acetone (2 samples) and 2-butanone (2 samples).

Subsurface Soils

For the entire site, 54 samples of subsurface soils were collected and analyzed from 26 locations for TCL VOCs. Subsurface soil samples analyzed for VOCs were collected in the Former Operational Areas only. The single location that exceeded the screening criteria is found in the Former Monarch HRDL. As discussed above, given the relatively large number of samples collected in the subsurface source areas at the site (i.e. the Former Operational Areas), VOC compounds do not appear to be associated with the contaminant impact identified at the site.

The analytical results of these samples are presented in Table 4-2B(CD). The frequency of detection and range of detected concentrations of VOCs are presented in Table 4-2G. One or more VOCs were detected in 42 samples. Of the VOCs on the TCL at the time of the testing, 16 were detected in the subsurface soils samples (listed in order of decreasing frequency): acetone (42 samples), 2-butanone (31 samples), carbon disulfide (29 samples), toluene (26 samples), xylenes (21 samples), ethylbenzene (9 samples), benzene (9 samples), 4-methyl-2-pentanone (5 samples), 2-hexanone (4 samples), methylene chloride (4 samples), chloroform (2 samples), tetrachloroethene (2 samples), carbon tetrachloride (1 sample), cis-l,3-dichloropropene (1 sample), 1,2-dichloroethene (1 sample), and 1,1,1-trichloroethane (1 sample). The location of the sample that exceeds the screening criteria is presented on Figure 4-2D.

4.2.1.4 TCL SVOCs in Soil Samples

Surface Soils

Only three samples of surface soils were collected and analyzed from three locations for TCL SVOCs for the entire site. Of the surface soil samples analyzed for SVOCs, one was collected from the Former Operational Areas and two were collected in the Residential/Commercial Areas (specifically in the area of the clay seam). The concentrations of SVOCs did not exceed any of the screening criteria for the respective compounds. The surface data set for SVOCs is limited, however, when considered in conjunction with the subsurface data set below, SVOC compounds appear to have a similar distribution, and appear to be associated with the contaminant impact identified at the site.

The analytical results of these samples are presented in Table 4-2C(CD). The frequency of detection and range of detected concentrations of SVOCs are presented in Table 4-2E. One or more SVOCs were detected in 2 samples. Of the SVOCs on the TCL at the time of the testing, 4 were detected in the surface soil samples (listed in order of decreasing frequency): 2-methylnaphthalene (2 samples), phenanthrene (2 samples), 4-methylphenol (2 samples), and chrysene (1 sample). The concentration of these SVOCs did not exceed the screening criteria for their respective compounds.

Subsurface Soil

Fifty-four samples of subsurface soils were collected and analyzed from 26 locations for TCL SVOCs. Subsurface soil samples analyzed for SVOCs were collected in the Former Operational Areas only. Roughly half of the samples analyzed for SVOCs had concentrations that exceeded the screening criteria, and the exceedances were evenly distributed in the Former Operational Areas. As discussed above, given the relatively large number of samples collected in the source areas at the site (i.e. the Former Operational Areas), and the relatively large abundance of detections above the screening criteria, SVOC compounds do appear to be associated with the contaminant impact identified at the site. Based upon the existing data at the OU, it is assumed that SVOC compounds are similarly distributed with the PCB impact associated with these other areas.

The analytical results of these samples are presented in Table 4-2D(CD). The frequency of detection and range of detected concentrations of SVOCs are presented in Table 4-2G. One or more SVOCs were detected in 28 samples of the 54 samples collected. Of the SVOCs on the TCL at the time of the testing, 19 were detected in the subsurface soils (listed in order of decreasing frequency): bis(2-ethylhexyl)phthalate (28 samples), 2-methylnaphthalene (26 samples), 4-methylphenol (17 samples), phenanthrene (17 samples), fluoranthene (9 samples), chrysene (5 samples), naphthalene (5 samples), pyrene (5 samples), benzo(a)anthracene (3 samples), benzo(a)pyrene (3 samples), benzo(b)fluoranthene (3 samples), benzo(k)fluoranthene (3 samples), anthracene (2 samples), carbazole (2 samples), di-n-butylphthalate (2 samples), fluorene (2 samples), benzo(g,h,i)perylene (1 sample), dibenzofuran (1 sample), and pentachlorophenol (1 sample). Semivolatiles were exceeded in fifteen samples. 4-methylphenol was the most frequently exceeded SVOCs and noted at twelve of the sample locations (Table 4-2H). The concentration of pentachlorophenol, naphthalene, and phenanthrene were each exceeded at three different locations. The location of samples that exceed the screening criteria are presented in Figure 4-2E.

4.2.1.5 TCL Pesticides in Soil Samples

Surface Soils

Only one sample of surface soils was collected from the site and analyzed for TCL pesticides. The one surface soil sample analyzed for pesticides was collected from the Former Operational Areas. The concentrations of pesticides did not exceed any of the screening criteria for the respective compounds. Although the surface data set are limited (i.e. one sample), when considered in conjunction with the subsurface data set discussed below, pesticide compounds do not appear to be associated with the contaminant impact identified at the site.

The analytical results of these samples are presented in Table 4-2E(CD). The frequency of detection and range of detected concentrations of pesticides are presented in Table 4-2E. There were no samples that exceeded the screening criteria. Of the pesticides on the TCL at the time of the testing, two compounds were detected in this sample: 4,4'-DDE, and 4,4'-DDT.

Subsurface Soils

Fifty-four samples of subsurface soils were collected from the site and analyzed from 26 locations for TCL pesticides. Subsurface soil samples analyzed for pesticides were collected in the Former Operational Areas only. None of these locations exceeded the screening criteria. Given the relatively large number of samples collected in the source areas at the site (i.e. the Former Operational Areas), pesticide compounds do not appear to be associated with the contaminant impact identified at the site.

The analytical results of these samples are presented in Table 4-2F(CD). The frequency of detection and range of detected concentrations of pesticides are presented in Table 4-2G. One or more pesticides were detected in 14 samples. Of the pesticides on the TCL at the time of the testing, 7 were detected in the subsurface soils and residuals samples (listed in order of decreasing frequency): aldrin (14 samples), 4,4'-DDT (13 samples), 4,4'-DDE (10 samples), gamma-chlordane (3 samples), 4,4'-DDD (3 samples), endrin aldehyde (3 samples), delta-BHC (2 samples), endosulfan I (2 samples), alpha-BHC (1 sample), beta-BHC (1 sample), and alpha-chlordane (1 sample). Many more subsurface residuals samples (36 samples) than subsurface soil samples were found to contain pesticides, and the pesticide concentrations were generally higher in the subsurface residuals samples than in the subsurface soil samples. However, the concentration of these pesticides did not exceed the screening criteria for its respective compound.

4.2.2 TAL Inorganic Constituents in Soil Samples

Some of the samples collected as part of the RI efforts carried out between 1993 and 2003 were analyzed for the CLP TAL analytes. These samples were either identified in the RI/FFS Work Plan (BBEPC, 1993a) or selected in the field by the MDEQ. The TAL includes a variety of inorganic contaminants including aluminum, arsenic, barium, beryllium, calcium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, sodium, vanadium, and zinc. The results of soil sample analyses for these compounds are presented below and these data are discussed for the various areas of the site when applicable.

As shown on Figures 4-2F through 4-2N, the majority of the samples analyzed for TAL contaminants were taken in operational areas. When these sample intervals are compared to the boring logs, it is clear that samples were collected from the waste/residuals or directly below them. Based on a review of the figures, tables and boring logs, it is shown that elevated concentrations of TAL contaminants, as compared to the statewide default background screening criteria RRD-1 Part 201 (MDEQ, 2004) are associated with the waste/residuals.

Surface Soil

For the entire site, two samples of surface soils were collected and analyzed from two locations for TAL inorganic constituents. Both samples were collected from the Former Operational Areas, and both samples exceeded the screening criteria for some of the TAL constituents. The surface data set for TAL constituents is limited, however, when considered in conjunction with the subsurface data set, certain TAL constituents appear to be associated with the contaminant impact identified at the site.

The analytical results of these samples are presented in Table 4-2G(CD). The frequency of detection and range of detected concentrations of inorganics are presented in Table 4-2E. One or more inorganics were detected in the two samples. Of the inorganics on the TAL at the time of the testing, 18 were detected in the surface soil samples (listed in order of decreasing frequency): aluminum (2 samples), barium (2 samples), calcium (2 samples), chromium (2 samples), cobalt (2 samples), copper (2 samples), iron (2 samples), lead (2 samples), magnesium (2 samples), manganese (2 samples), nickel (2 samples), potassium (2 samples), vanadium (2 samples), zinc (2 samples), arsenic (1 sample), beryllium (1 sample), mercury (1 sample), and sodium (1 sample). The following metals exceeded their respective screening criteria: aluminum, arsenic, chromium, iron, lead (Table 4-2F). The location of these samples that exceed the screening criteria are presented in Figure 4-2F.

Subsurface Soils

For the entire site, 55 samples of subsurface soils were collected and analyzed from 27 locations for TAL inorganic constituents. Subsurface soil samples analyzed for the TAL constituents were collected in the Former Operational Areas only. Most of the samples analyzed for TAL constituents had concentrations that exceeded the screening criteria, and those exceedances were evenly distributed in the Former Operational Areas. As discussed above, given the relatively large number of samples collected in the source areas at the site (i.e. the Former Operational Areas), and the relatively large abundance of detections above the screening criteria, TAL constituents do appear to be associated with the contaminant impact identified at the site. Based upon the existing data at the OU, it is assumed that TAL constituents are similarly distributed with the PCB impact associated with these other areas.

The analytical results of these samples are presented in Table 4-2H(CD). The frequency of detection and range of detected concentrations of inorganics are presented in Table 4-2G. One or more inorganics were detected in 55 samples. Of the inorganics on the TAL at the time of the testing, 23 were detected in the subsurface soils (listed in order of decreasing frequency): aluminum (55 samples), calcium (55 samples), chromium (55 samples), copper (55 samples), iron (55 samples), manganese (55 samples), vanadium (55 samples), magnesium

(55 samples), arsenic (53 samples), lead (52 samples), barium (50 samples), nickel (50 samples), zinc (45 samples), cobalt (44 samples), potassium (33 samples), cyanide (29 samples), mercury (27 samples), beryllium (24 samples), selenium (18 samples), sodium (15 samples), cadmium (10 samples), antimony (7 samples), and thallium (1 sample). The following metals exceeded their respective screening criteria: aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, mercury, nickel, selenium, and zinc. The sample locations corresponding to the sample parameters (aluminum, barium, chromium, copper, cyanide, lead, mercury, and zinc) that had the highest frequency of detections of above the screening criteria are presented in Figure 4-2G through Figure 4-2N, respectively.

4.3 Sediment Investigation

The sediment investigation included the collection and chemical analysis of 950 samples of sediments at 608 locations throughout the Allied OU study areas between 1991 and 2003. Sediment samples, for purposes of this RI, are defined as any solid matrix (sediment or residuals) that was collected from an area 1) within the Portage Creek channel or other surface water body and 2) within an area adjacent to Portage Creek that may be inundated during a high flow event. As the area of inundation has not yet been defined for the OU, some samples currently identified as sediment may be reclassified as soil in the future and vice versa. The sediment data collected at the Allied OU since 1991 for TCL constituents, TAL constituents, and PCBs are summarized in this section of the report. It should be noted that much of the data classified as surface sediment (0 to 2 feet below ground level [bgl]) was classified based on its depth at the time of collection. Many of these shallow samples have since been covered by backfill and the current sample depths were not calculated and may be greater than two feet. This is most likely to be the case with confirmation samples collected as part of the Removal Action.

Much of the sediment data for the site is located in the Former Bryant Mill Pond. As discussed in previous sections of this RI, the Removal Action resulted in the excavation of approximately 150,000 cy of sediment. This removal action had a profound and positive effect on the overall sediment quality at the site. Details regarding the activities associated with the Removal Action can be found in the USACE Final Report (USACE, 2000). For purposes of this RI, only the post Removal Action data are discussed for this area.

Table 2-8 presents a summary of the sediment samples submitted for chemical analysis during the RI. Table 4-3A through Table 4-3H summarizes the frequency of detection and range of detected concentrations for the constituents in sediment samples that represent current conditions. The analytical results for split samples collected by the MDEQ and USEPA are similarly summarized in Table 4-3A through Table 4-3H. The data for individual samples of sediments collected by MHLLC for the RI are presented in Table 4-2A(CD) through Table 4-2M(CD) and Table 4-5A(CD) through Table 4-5C(CD). MDEQ and USEPA data are presented in Appendix MDEQ - B and Appendix USEPA, respectively.

Sample locations near the edge of the removal action excavation can be used to describe the nature of the waste material excavated. Therefore, these data can be used as a conservative measure of the nature of the waste material in adjacent areas that remains unexcavated.

Screening Criteria

As indicated above, the State generic criteria for soil do not differentiate between soil and sediment. However, the PCB criteria developed in the site specific BERA and HHRA consider the differences between the soil and sediment matrices and as such, have developed criteria for both which are summarized above at the beginning of this section. As an initial screening, all laboratory results were compared to Table 2 of RRD Operational Memorandum No. 1, Part 201Generic Cleanup Criteria and Screening Levels (12/23/06) of Part 201.

4.3.1 TCL Compounds in Sediment Samples

Some of the sediment samples collected as part of the RI efforts carried out between 1991 and 2003 were analyzed for the CLP TCL compounds. These samples were either identified in the RI/FFS Work Plan (BBEPC, 1993a) or selected in the field by the MDEQ. The TCL includes a variety of PCBs, PCDDs and PCDFs VOCs, SVOCs, and pesticides. The results of sediment sample analyses for these compounds are presented below and these data are discussed for the various areas of the site when applicable.

Samples were collected during the sediment investigation to characterize the nature and extent of PCBs present at the site. Surface and subsurface samples of sediments were collected during several phases of investigation conducted between 1991 and 2003.

4.3.1.1 PCBs in Sediment Samples

Surface Sediment

There were 637 samples of surface sediment collected and analyzed for PCB analysis; four samples were by congener. Of the total samples collected, 98 have been subsequently excavated due to IRM activities at the site.

Surface sediment samples analyzed for PCBs were collected in the Former Bryant Mill Pond, the Former Operational Areas, and Residential/Commercial areas. The data suggests that the vast majority of samples collected at the site (specifically from the Former Bryant Mill Pond as part of the Removal Action confirmation sampling) had concentrations of PCBs below the screening criteria. The areas where concentrations of PCBs in the surface sediment exceed the screening criteria include those adjacent to the Former Operation Areas (along Portage Creek in the vicinity of sheetpile [SP-418 to SP-611 and SP-82 to SP-254], near the contaminated groundwater seeps [seep G, H, I, and J], and north of the Western Disposal Area in the Panelyte Marsh) and a few isolated locations along Portage Creek. For the most part, surface sediment contamination is in areas directly adjacent to identified soil impact.

The analytical results of these samples are presented in either Table 4-2J(CD), Table 4-2L(CD), Table 4-5B(CD), or Table 4-5C(CD) - due to reclassification of matrix type. The frequency of detection and range of detected concentrations of total PCBs in samples that have not been excavated are presented in Table 4-3A. Table 4-3B presents the location and values of PCB exceedances. The location of these samples with PCB concentrations exceeding the screening criteria are presented in Figure 4-3A.

Subsurface Sediment

There were 309 samples of subsurface sediment collected and analyzed for PCB analysis (six samples were by congener). However, 63 of these locations have been excavated due to IRM activities at the site. Subsurface sediment samples analyzed for PCBs were collected in the Former Bryant Mill Pond, the Former Operational Areas, and Residential/Commercial Areas. The data suggests that the majority of subsurface sediment samples collected at the site had concentrations of PCBs below the screening criteria. The areas where concentrations of PCBs in the subsurface sediment exceed the screening criteria include those adjacent to the Former Operation Areas (along Portage Creek in the vicinity of the sheetpile [SP-537 to SP-607, and SP-416 to SP-451]), adjacent to the Residential/Commercial areas (near the East Bank Area and residences near Golden Age) and a few isolated locations along Portage Creek. Generally, the subsurface sediment contamination is in a subset of areas directly adjacent to identified soil impact.

The analytical results of these samples are presented in Table 4-2K(CD), Table 4-2M(CD), Table 4-5B(CD), or Table 4-5C(CD) - due to reclassification of matrix type. The frequency of detection and range of detected concentrations of total PCBs in samples that have not been excavated are presented in Table 4-3C. Table 4-3D presents the sampling locations where the concentration of total PCBs exceed the screening criteria. These sampling locations having PCB exceedances are presented in Figure 4-3B.

4.3.1.2 PCDDs and PCDFs in Sediment Samples

No samples collected at the site, and classified as surface or subsurface sediment, were analyzed for the presence of PCDDs and PCDFs.

4.3.1.3 TCL VOCs in Sediment Samples

Surface Sediment

For the entire site, four samples of surface sediment were collected and analyzed for TCL VOCs, two of which have since been excavated due to IRM activities at the site. Of the surface sediment samples analyzed for VOCs, the two remaining samples were collected from the Residential/Commercial areas, specifically from the clay seam area. The concentrations of VOCs did not exceed any of the screening criteria for the respective compounds. When these data are considered in conjunction with the previous soil data set discussed in the soil subsection above, VOC compounds are probably not associated with the contaminant impact identified at the site.

The analytical results of these samples are presented in Table 4-2A(CD) due to reclassification of matrix type. The frequency of detection and range of detected concentrations of VOCs in samples that have not been excavated are presented in Table 4-3E. One or more VOCs were detected in the two unexcavated samples. Of the VOCs on the TCL at the time of the testing, one VOC was detected in one of the surface sediment samples (acetone). The concentration of acetone did not exceed its respective screening criteria.

Subsurface Sediment

For the entire site, two samples of subsurface sediment were collected and analyzed for TCL VOCs. Due to IRM excavation activities at the site, these sample locations no longer exist and none of the detected VOCs exceeded their screening criteria. Of the subsurface sediment samples analyzed for VOCs, the two excavated samples were collected from the Former Bryant Mill Pond. The concentrations of VOCs did not exceed any of the screening criteria for the respective compounds. Although the subsurface data set are also too limited to draw reliable conclusions, when considered in conjunction with the previous soil data set discussed in the soil subsection above, VOC compounds are probably not associated with the contaminant impact identified at the site. The analytical results of these samples are presented in Table 4-2B(CD) due to reclassification of matrix type.

4.3.1.4 TCL SVOCs in Sediment Samples

Surface Sediment

Only four samples of surface sediment were collected and analyzed for TCL SVOCs, two of which have been subsequently excavated due to IRMs at the site. Of the surface sediment samples analyzed for SVOCs, the two remaining samples were collected from the Former Operational Areas and the Former Bryant Mill Pond. The concentrations of SVOCs at one sample location in the Western Disposal Area exceeded the screening criteria for the respective compounds. When these data are considered in conjunction with the previous soil data set discussed in the soil subsection above, SVOC compounds are likely to be associated with the PCB impact identified in the sediments at the site.

The analytical results of the unexcavated samples are presented in Table 4-2C(CD) (due to reclassification of matrix type). The frequency of detection and range of detected concentrations of SVOCs in samples that have not been excavated are presented in Table 4-3E. One or more SVOCs were detected in the two unexcavated samples. Of the SVOCs on the TCL at the time of the testing, 12 were detected in the surface sediment samples (listed in order of decreasing frequency): chrysene (2 samples), fluoranthene (2 samples), pyrene (2 samples), 2-methylnaphthalene (1 sample), acenaphthene (1 sample), anthracene (1 sample), benzo(b)fluoranthene (1 sample), carbazole (1 sample), dibenzofuran (1 sample), flourene (1 sample), naphthalene (1 sample), and phenanthrene (1 sample). The SVOCs (acenaphthene, carbazole, dibenzofuran, naphthalene, and phenanthrene) detected in one sample exceeded their respective screening criteria as presented in Table 4-3F. The sample location that had SVOC exceedances is shown in Figure 4-3C.

Subsurface Sediment

For the entire site, two samples of subsurface sediment were collected and analyzed for TCL SVOCs. However the location of these two samples were excavated due to IRMs at the site. The two excavated samples were collected from the Former Bryant Mill Pond. The concentrations of SVOCs at one sample location exceeded the screening criteria for the respective compounds. When these data are considered in conjunction with the previous soil data set discussed in the soil subsection above, SVOC compounds are likely to be associated with the PCB impact identified in the sediments at the site.

The analytical results of these samples are presented in Table 4-2D(CD). The concentrations of

2,4-dimethylphenol, phenol, and 2-methylphenol in one of the samples (sample location ID A60619) exceeded the respective screening criteria.

4.3.1.5 TCL Pesticides in Sediment Samples

Surface Sediment

Only three samples of surface sediment were collected and analyzed for TCL pesticides, however two of which have been excavated due to IRM activities at the site. The three surface sediment samples analyzed for pesticides were collected from the Former Operational Areas and the Former Bryant Mill Pond. The concentrations of pesticides did not exceed any of the screening criteria for the respective compounds. When considered in conjunction with the previous soil data set discussed in the soil subsection above, pesticide compounds do not appear to be associated with the contaminant impact identified at the site.

The analytical results of these samples are presented in Table 4-2E(CD) (due to reclassification of matrix type). The frequency of detection and range of detected concentrations of pesticides in the one sample that has not been excavated is presented in Table 4-3E. One or more pesticides were detected in this single sample. Of the pesticides on the TCL at the time of the testing, two were detected in the surface soil samples: 4,4'-DDE, and 4,4'-DDT. The concentration of these individual pesticides did not exceed their respective screening criteria.

Subsurface Sediment

For the entire site, only two samples of subsurface sediment were collected and analyzed for TCL pesticides. The locations of these two samples have been excavated due to IRM activities at the site. The two subsurface sediment samples analyzed for pesticides were collected from the Former Bryant Mill Pond. The concentrations of pesticides did not exceed any of the screening criteria for their respective compounds. When considered in conjunction with the previous soil data set discussed in the soil subsection above, pesticide compounds do not appear to be associated with the contaminant impact identified at the site.

The analytical results of these two samples are presented in Table 4-2F(CD) - due to reclassification of matrix type. Even though pesticides were detected (i.e., 4,4'-DDE, 4,4'-DDT, aldrin, and endrin aldehyde), the concentrations of each were not above their respective screening criteria.

4.3.2 TAL Inorganic Constituents in Sediment Samples

Some of the samples collected as part of the RI efforts carried out between 1993 and 2003 were analyzed for the CLP TAL analytes. These samples were either identified in the RI/FFS Work Plan (BBEPC, 1993a) or selected in the field by the MDEQ. The TAL includes a variety of inorganic contaminants including aluminum, arsenic, barium, beryllium, calcium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, sodium, vanadium, and zinc. The results of sediment sample analyses for these compounds are presented below and these data are discussed for the various areas of the site when applicable.

Surface Sediment

Seven samples of surface sediment were collected and analyzed for TAL inorganic constituents, five of which have been subsequently excavated due to IRM activities at the site. The samples were collected from the Former Operational Areas and the Former Bryant Mill Pond. Two of the seven samples exceeded the screening criteria for some of the TAL constituents. When these data are considered in conjunction with the previous soil data set discussed in the soil subsection above, TAL constituents do appear to be associated with the PCB impact identified at the site.

The analytical results of these samples are presented in Table 4-2G(CD) - due to reclassification of matrix type. The frequency of detection and range of detected concentrations of inorganics in samples that have not been excavated are presented in Table 4-3E. One or more inorganics were detected in the two samples. Of the inorganics on the TAL at the time of the testing, 20 were detected in the surface sediment samples (listed in order of decreasing frequency): aluminum (2 samples), barium (2 samples), calcium (2 samples), chromium (2 samples), cobalt (2 samples), copper (2 samples), iron (2 samples), lead (2 samples), magnesium (2 samples), manganese (2 samples), nickel (2 samples), potassium (2 samples), vanadium (2 samples), zinc (2 samples), arsenic (1 sample), beryllium (1 sample), cadmium (1 sample), mercury (1 sample), sodium (1 sample), and selenium (1 sample). The following metals were detected above their respective screening criteria as presented in Table 4-3F: arsenic, barium, chromium, iron, lead, selenium, and zinc. The location of samples that exceed the screening criteria are presented in Figure 4-3D.

Subsurface Sediment

Seven subsurface sediment samples were collected and analyzed for TAL inorganic constituents. However, six of these locations have subsequently been excavated due to IRM activities at the site. The samples were collected from the Former Bryant Mill Pond. Only one of the seven samples exceeded the screening criteria for some of the TAL constituents. When these data are considered in conjunction with the previous soil data set discussed in the soil subsection above, TAL constituents do appear to be associated with the PCB impact identified at the site.

The analytical results of these samples are presented in Table 4-2H(CD) - due to reclassification of matrix type. The frequency of detection and range of detected concentrations of inorganics in sample that has not been excavated are presented in Table 4-3G. Of the inorganics on the TAL at the time of the testing, 20 were detected in the subsurface sediment samples: aluminum (1 sample), barium (1 sample), beryllium (1 sample), calcium (1 sample), chromium (1 sample), cobalt (1 sample), copper (1 sample), cyanide (1 sample), iron (1 sample), lead (1 sample), magnesium (1 sample), manganese (1 sample), mercury (1 sample), nickel (1 sample), potassium (1 sample), selenium (1 sample), silver (1 sample), sodium (1 sample), vanadium (1 sample), and zinc (1 sample). Of the 20 detections, the following ten constituents exceeded their respective screening criteria as presented in Table 4-3H: barium, chromium, copper, iron, lead, mercury, nickel, selenium, silver, and zinc. The location of this sample having metals that exceeded their respective screening criteria is presented in Figure 4-3E.

4.4 Hydrogeological Investigation

The hydrogeological investigation was designed to identify the constituents of interest in groundwater at the Allied OU and evaluate their vertical and horizontal extent. This investigation was conducted in a number of phases beginning in 1993. An extensive network of wells was used to characterize groundwater within each study area as well as groundwater discharging from the study areas to Portage Creek. At two locations (gas vent GV-10 and monitoring well MW-125P) samples are considered representative of leachate. As discussed in Section 2.4.3 of this report, leachate is defined as liquid produced exclusively from residual material.

This report recognizes that the groundwater within Kalamazoo County has naturally high concentrations of arsenic and other inorganic constituents. Information on the levels of inorganic constituents is available on the Kalamazoo County website. The background levels of inorganic constituents are relevant and will be considered in the generation of remedy alternatives in the FS.

Since the start of the hydrogeological investigation, the array of wells has evolved from an initial group of 50 monitoring wells (47 of which were sampled during the RI) to the current inventory of 111 monitoring wells, piezometers, and observation wells. Over the course of the RI, MHLLC installed 40 piezometers and observation wells and 90 monitoring wells, enabling the collection of hydrogeological data from 177 unique locations. As discussed in Section 2.4.8, 69 wells and piezometers were decommissioned for various reasons during five separate events. The existing and former wells used in the hydrogeological investigation are listed on Table 2-4 and their locations are shown on Figure 8. Details regarding the chemical analytical results for groundwater sampling activities conducted from 1993 to 1998 are discussed in Section 3.3 of *Technical Memorandum 7* (BBL, 1997c) and Section 3.3 of the *Addendum to Technical Memorandum 7* (BBL, 1999). The relevant results from these earlier groundwater sampling activities are summarized as appropriate in the following sections, along with more detailed discussions of the findings of subsequent investigation phases. The groundwater and leachate investigations included the collection and chemical analysis of 366 samples of groundwater and leachate at 104 locations throughout the study area between 1993 and 2003.

4.4.1 Groundwater and Leachate Sample Analytical Results

Prior to and throughout the RI, PCBs were recognized as the primary COC in environmental media at the site. As a result, groundwater and leachate samples collected during each phase of the hydrogeological investigation were analyzed for PCBs. In addition, samples collected from the monitoring wells and piezometers were analyzed for a variety of general water quality parameters and other constituents, including VOCs, SVOCs, pesticides, and inorganics to further characterize groundwater and leachate quality at the site. Field parameters (temperature, pH, conductivity, DO, turbidity, and/or ORP) were measured during purging and sample collection, and were recorded in field sampling documentation included in Appendix A.

Hundreds of groundwater samples and a limited number of leachate samples have been collected to characterize the nature and extent of PCBs at the Allied OU. Data obtained during the earlier rounds of sampling demonstrated the importance of proper well installation, development, and sampling methods. Refinements were made to these procedures in an effort to acquire the most representative samples practical. These efforts succeeded in reducing the concentrations of TSS in groundwater samples at the site and there has also been a corresponding reduction in the concentration of PCBs in samples collected after those refinements from the same wells. Early rounds of sampling from monitoring wells followed USEPA low flow requirements. Groundwater samples generally were collected from the wells after a minimum of three well volumes had been purged and once the field parameters had stabilized. In later rounds, an ultra-low flow sampling approach was adopted, wells were redeveloped more aggressively, and potentially compromised wells were replaced with double-cased wells in an attempt to further promote the collection of representative samples. The ultra-low flow sampling included the following measures:

- Where possible, groundwater samples were collected using a peristaltic pump. If a peristaltic pump could not be used, a submersible electric pump was used. A Teflon bailer was employed only for those wells in which neither pump could be used;

- At least 24 hours prior to sampling, dedicated 3/8-in diameter, low-density polyethylene (LDPE) tubing was placed into each well to be pumped, with the bottom of the tubing set at approximately the screen midpoint (typically 2.5 ft above the bottom of the well screen for a 5-feet long screen);

- A pump was connected to the tubing and a flow-through-cell;

- The wells were purged and sampled at pumping rates between 20 and 80 ml/minute to minimize drawdown and groundwater entrance velocity;

- Field parameters were recorded at regular intervals until parameter stabilization had been reached. The following ranges for specific parameters were considered necessary to attain parameter stabilization prior to sampling: water level (+/- 0.3 feet), pH (+/- 0.1 unit), DO (+/- 10%), conductivity (+/- 3%), ORP (+/- 10 millivolt [mV]); and

- Samples were collected with the lowest turbidity reading as technically achievable. If turbidity values exceeded 5 nephelometric turbidity units (NTUs) during purging, adjustments were made to the sampling setup (e.g., reduced pump flow, raised influent tube) to minimize turbidity.

The groundwater and leachate sample analytical data and QA/QC reports are included in Appendix K. Groundwater and leachate samples collected for the RI were generally unfiltered. Groundwater and leachate samples were collected using the same sampling techniques. Table 2-6 presents a summary of the groundwater and leachate samples submitted for chemical analysis during the RI. The constituent-specific analytical results for the 525 groundwater and leachate analyses conducted over the past 10 years are presented in Table 4-3A(CD) through Table 4-4D(CD). Due to the volume of groundwater data and various sampling techniques, the groundwater will be discussed per the seven individual sampling events that occurred in 1993, 1995, 1997, 1998, 2000-2001, 2002, and 2003 where applicable.

Screening Criteria

For the purposes of developing the COCs for the Allied OU, applicable media are compared to the MDEQ generic criteria for groundwater. As an initial screening, all laboratory results were compared to Table 1 of RRD Operational Memorandum No. 1, Part 201Generic Cleanup Criteria and Screening Levels (12/23/06) of Part 201. Determination of the applicability of cleanup criteria for groundwater at the Allied OU will be made by the USEPA, in consultation with the MDEQ, during the review of ARARs in the FS.

4.4.1.1 PCBs in Groundwater and Leachate Samples

During the course of the study (1993, 1995, 1997, 1998, 2000-2001, 2002, and 2003 sampling events) 357 unfiltered and 18 filtered groundwater samples and 4 unfiltered leachate samples were collected for PCB analysis. Figure 36A presents the pre-IRM distribution of PCB concentrations in groundwater and groundwater seeps. The PCB analytical results for groundwater and leachate samples collected by MHLLC and split samples collected by the MDEQ are summarized in Tables 4-3D(CD) and Appendix MDEQ - B, respectively. The frequency of detection and range of detected concentrations, as well as the number of exceedances of the screening criteria of PCBs in groundwater and leachate samples collected by MHLLC and split samples collected by the MDEQ are presented by study area in Table 4-4A and Table 4-4B, respectively.

Many rounds of groundwater sampling were conducted for the hydrogeological investigation between 1993 and 2003 to characterize the nature and extent of PCBs in groundwater and leachate at the Allied OU. Data obtained during the earlier rounds of sampling demonstrated the importance of proper well installation, development, and sampling methods. Refinements were made to these procedures in an effort to acquire the most representative samples practical. Earlier phases of groundwater samples (those collected prior to 1999) are described in greater detail in the *Addendum to Technical Memorandum 7, October 1999.* The earlier data are of less value than the current data for selecting a remedy for the site.

There are a few important issues to consider regarding why the presence of PCBs in samples of groundwater and leachate exists. As discussed in more detail in Section 5, due to their physicochemical properties, PCBs in a soil and water environment are generally found adsorbed onto solids, especially organic solids. A fraction of PCBs may also partition into a dissolved phase, which may then move with leachate and/or groundwater or become adsorbed again to a solid substrate.

Much of the difficulty in interpreting PCB analytical results for groundwater and leachate samples arises from the question of whether the detected concentrations represent the mobile fraction of PCBs. The 1997 groundwater sampling event was implemented to address the above concern by evaluating any potential difference in filtered and unfiltered analytical results given the assumption that larger particles are not mobile in the groundwater. The results of this groundwater sampling event identified no statistically significant difference in the results of PCB in the filtered samples in comparison to the unfiltered samples as presented in Table 4-4A and Table 4-4B. In any case, considerable effort was made over the course of the RI at the Allied OU to refine well design, construction, development, and sampling techniques to obtain samples of groundwater and leachate that are representative of *in situ* conditions.

All of the efforts were undertaken in an attempt to best reflect the nature and extent of PCB contamination in groundwater at the Allied OU. Further, the sampling conducted after 2001 best reflects the characterization of site groundwater today.

1993 Data

Groundwater samples were collected from 52 monitoring wells (51 monitoring wells and one leachate sample was collected from monitoring well MW-125P). These wells were located throughout the Former Operational Areas and Former Bryant Mill Pond in areas of PCB soil and sediment impact. PCBs were detected in 8 of the 57 groundwater samples collected at site (which includes duplicate samples). The frequency of detection and range of detected concentrations of PCBs are presented in Table 4-4A. Of the eight groundwater samples where PCBs were detected, all eight groundwater samples (MW-25, MW-5, MW-120B, MW-121A, MW-121B, MW-22A, MW-24, and MW-8A) exceeded the screening criteria. Concentrations that exceeded the screening criteria ranged from 0.89 to 4.9 μg/L and are presented in Table 4-4B. Figure 4-4A present the location of these exceedances for the 1993 – 1998 sampling events (which includes this sampling event).

1995 Data

The MDEQ requested that a second sampling event be conducted in 1995 using a lower method detection limit (MDL) for PCB analysis from each of the 52 monitoring wells previously sampled in 1993 (51 monitoring wells and one leachate sample was collected from monitoring well MW-125P). These wells were located throughout the Former Operational Areas and Former Bryant Mill Pond in areas of PCB soil and sediment impact. PCBs were detected in 9 of 55 groundwater samples (which includes duplicate samples). The frequency of detection and range of detected concentrations of PCBs are presented in Table 4-4A. Of the nine groundwater samples where PCBs were detected, eight samples (MW-5, MW-120B, MW-121A, MW-121B, MW-126A, MW-22A, MW-24, and MW-8A) exceeded the screening criteria. Concentrations that exceeded the screening criteria ranged from 0.22 to 1.4 μg/L and are presented in Table 4-4B. Figure 4-4A presents the locations of these exceedances for the 1993 to 1998 sampling events (which includes this sampling event).

1997 Data

During 1997, two separate sampling events (March and July) were conducted. In March, filtered groundwater samples were collected from 10 of the 11 monitoring well locations where PCBs had been detected in the previous sampling events. The 1997 groundwater sampling event was implemented to evaluate any potential difference in filtered and unfiltered analytical results given the assumption that larger particles are not mobile in the groundwater. Both filtered (11 samples) and unfiltered (18 samples) groundwater samples were analyzed for PCBs and TOC. The results of this groundwater sampling event identified no statistically significant difference in the results of PCBs in the filtered samples in comparison to the unfiltered samples as presented in Table 4-4A and Table 4-4B. The frequency of detection and range of detected concentrations of PCBs are presented in Table 4-4A. PCBs were detected in 10 of the 11 filtered samples while only 5 locations exceeded the screening criteria (MW-5, MW-120B, MW-121A, MW-22A, and MW-8A). Concentrations that exceeded the screening criteria in the filtered samples ranged from 0.26 to 1.1 μg/L. PCBs were detected in 17 of the 18 unfiltered samples while 8 locations exceeded the screening criteria (MW-5, MW-120B, MW-121A, MW-121B, MW-126A, MW-22A, and MW-8A). Concentrations that exceeded the screening criteria in the unfiltered samples ranged from 0.25 to 1.0 μg/L. Table 4-4B presents the locations where the concentration of PCBs exceeded the screening criteria. Figure 4-4A present the location of these exceedances for this sampling event and through the 1998 sampling event.

A second sampling event in July 1997 was conducted to test the hypothesis that purging of wells prior to sampling would result in a lower concentration of PCB during sampling. This sampling activity consisted of a purge and sample sequence where a volume of water (e.g. 10 gallons) was purged from MW-120B and MW-121B, then a sample was collected. Sample A was collected after 10 gallons were purged, sample B was collected after 20 gallons were purged, and Sample C was collected after 30 gallons were purged. All three samples collected from MW120B yielded concentrations above the screening criteria (A- 0.42 μg/L, B – 0.39 μg/L, C-0.39 μg/L). All three samples collected from MW-121B yielded concentrations above the screening criteria (A- 0.30 μg/L, B – 0.29 μg/L, C-0.25 μg/L). As PCBs were detected in all samples at similar concentrations above the respective screening criteria (see Table 4-4B), no practical differences were seen.

1998 Data

In 1998, three sampling events (May, August /October, and December) were performed (multiple groundwater samples were collected from a given well in 1998) on a limited number of recently installed double cased monitoring wells. During the May, August/October, and December 1998 sampling events, groundwater samples were collected from seven wells, seven wells, and five wells, respectively. During these sampling events, the same wells were sampled except for the December event, of which only five of these wells were sampled. The majority of these wells were designed as double cased replacement wells for select single cased wells, in which the data quality was questioned. MHLLC had advanced the concern that select single cased wells may not have provided samples representative of in-situ conditions. In an attempt to address this concern, MHLLC was given the opportunity to replace questionable wells with double cased wells. Given the primary mode of PCB transport conceptualized at this site (i.e., particulate transport), the utility of these wells to act as effective replacement wells is limited. For details related to contaminant fate and transport at the site, refer to Section 5 in this report. During the May sampling event, only one well (MW-122AR) indicated the presence of PCBs above the screening criteria (0.6 μg/L). During the August and October sampling, two wells (MW-122AR and MW-22AR) indicated the presence of PCBs, of which one sample was above the screening criteria (MW-122AR, 0.33 μg/L). During the December sampling event, the same wells identified in the previous event had detectable concentrations of PCBs, of which, the same well (MW-122AR) had PCB concentrations above its screening criteria (0.44 μg/l). The scope of these sampling events was limited. Given this fact, these activities simply support the concept that at locations with properly installed and sampled monitoring wells, PCBs can be found in the groundwater. The frequency of detection and range of detected concentrations of PCBs are presented in Table 4-4E and exceedances are presented in Table 4-4B. Figure 4-4A presents the location of these exceedances for this sampling event and the past sampling events.

2000-2001 Data

In 2000 - 2001, five sampling events (October/November 2000, January 2001, April 2001, August 2001, and October/November 2001) were performed from a limited number of recently installed double cased monitoring wells (MW-200A, MW-201B, MW-202B, MW-203B, MW-204B, and MW-205B). A total of 77 groundwater samples were collected from these six wells during this sampling period. These wells were installed during the IRM and monitoring well screens were intended to intersect flow paths that may occur beneath or around the sheet pile wall toward Portage Creek. PCBs were not detected in any of these wells during any of these sampling events. It is worth noting that five of the six wells (i.e., MW-201B, MW-202B, MW-203B, MW-204B, and MW-205B) are screened within the lower sand unit. Two of the wells (MW-204B and MW-205B) are located below the various confining units at the site. This data does suggest however, that PCBs are likely not underflowing the sheetpile in this southwest portion of the Bryant HRDLs and FRDLs.

2002 Data

In 2002, two sampling events were conducted in February and May which included the collection of 24 groundwater samples from 6 monitoring wells during this period (12 samples were collected by MHLLC and 12 samples were split by MDEQ). These two sampling events included the same 6 monitoring wells as the 2000 and 2001 events (MW-200A, MW-201B, MW-202B, MW-203B, MW-204B, and MW-205B). Laboratory results for the six wells sampled during both the February and May sampling events did not indicate the presence of PCBs.

The third event conducted in October/November was the most comprehensive sampling event since 1993 and included the collection of 61 samples, which included 59 groundwater samples from 38 monitoring wells and 2 leachate samples from gas vent GV-10 (42 samples including duplicates were collected by MHLLC and 19 split samples including duplicates were collected by MDEQ). PCBs were detected in 13 of the 59 groundwater and 2 of 2 leachate samples. The frequency of detection and range of detected concentrations of PCBs are presented in Table 4-4A. Of the thirteen groundwater samples where PCBs were detected, six of the groundwater (MW-8A, FW-101/MW-206P, MW-122AR) and two of leachate samples (GV-10) exceeded the screening criteria. PCB concentrations that exceeded the screening criteria for groundwater samples ranged from 0.25 to 0.549 μg/L and for leachate samples ranged from 0.847 to 2.5 μg/L and are presented in Table 4-4B. Figure 4-4A present the location of these exceedances for the 1993 – 1998 sampling events (which includes this sampling event). This comprehensive sampling event collected groundwater and leachate samples from wells that were located in and adjacent to the Former Operational Areas with the vast majority of wells located along the sheetpile of the Bryant HRDLs and FRDLs, and along Portage Creek near the Monarch HRDL. For the most part, these wells were constructed in or along expected flow paths to Portage Creek. As illustrated on Figure 4-4B, detectable levels of PCBs in groundwater occur across the site.

2003 Data

In 2003, one sampling event was performed in April/May which included the collection of 50 groundwater samples from 37 monitoring wells (41 samples including duplicates were collected by MHLLC and 9 split samples were collected by MDEQ). PCBs were detected in 4of the 50 groundwater samples. The frequency of detection and range of detected concentrations of PCBs are presented in Table 4-4A. There were no samples that exceeded the PCB screening criteria. Figure 4-4B presents the location of PCB detections and exceedances for the 2002 and 2003 sampling events. Groundwater samples were collected during this comprehensive sampling event from wells that were located in and adjacent to the Former Operational Areas with wells located along the sheetpile of the Bryant HRDLs and FRDLs, and along Portage Creek near the Monarch HRDL and Former Type III Landfill. For the most part, these wells were constructed in or along expected flow paths to Portage Creek. As before, detectable levels of PCBs in groundwater are present at the site. Because the wells included in the sampling events differ between 2002 and 2003, the nature and extent of PCB contamination in groundwater can not be drawn from either event on its own. For this reason, the 2002 and 2003 data sets should be considered collectively for the most accurate depiction of current groundwater conditions. Additional monitoring will be necessary to evaluate the groundwater at the site. Given the close proximity of many of these sample locations to the creek, similar concentrations of PCBs are expected to extend to the surface water at the site.

4.4.1.2 TCL VOCs, SVOCs, Pesticides, and TAL Inorganics in Groundwater and Leachate Samples

Groundwater or leachate samples were collected and analyzed for TCL VOCs, SVOCs, TAL inorganics, and pesticide analyses during the 1993 sampling event. Samples collected during the 2003 sampling event were analyzed for TCL VOCs and SVOCs only. Samples were not collected for analysis during the 1997, 1998, and 2000-2001 sampling events for TCL VOCs, SVOCs, or pesticide analyses. TAL inorganic sample analyses were performed in 1993, 2002, and 2003.

During the 1993 sampling event 51 wells were sampled and an additional 2 wells were sampled during the 2003 sampling event (which resulted in 60 groundwater samples). One sample of leachate was collected in this time period. All samples were analyzed for TCL VOCs and SVOCs during these events. Fifty-seven samples collected from 51 wells and one leachate sample were analyzed for pesticides during a round of sampling conducted in September and October 1993. Samples for TCL VOCs, SVOCs, and pesticide analyses were not collected during the 1995, 1997, 1998, 2000-2001, and 2002 sampling events. The laboratory analytical results for these samples are summarized in Table 4-3B(CD). The concentrations of detected compounds in groundwater and leachate samples are summarized by study area in Table 4-4C along with a summary of the range of concentrations, and frequency of detection. The location of any sampling point having exceedances of TCL VOCs, SVOCs, TAL inorganics, and pesticides are presented in Table 4-4D.

During the course of the study (i.e., September-October 1993, October-November 2002, and April-May 2003 sampling events), 130 unfiltered and 57 filtered groundwater samples, and 2 unfiltered and one filtered leachate samples were collected for TAL inorganics analysis. The TAL inorganic constituents include 23 metals and cyanide. Unfiltered groundwater samples collected in September-October 1993, October-November 2002, and April-May 2003 were analyzed for the TAL constituents. Filtered groundwater samples collected during the 1993 sampling event (i.e. utilizing a 0.45 micron filtering device) were also analyzed for these constituents. Samples for filtered or unfiltered TAL inorganic analyses were not collected during the 1995, 1997, 1998, and 2000-2001 sampling events.

These wells were located throughout the Former Operational Areas and Former Bryant Mill Pond in areas of PCB soil and sediment impact. PCBs were detected in 8 of the 57 groundwater samples collected at site (which includes duplicate samples).

VOCs

1993 Data

Groundwater samples were collected from 52 monitoring wells (51 monitoring wells and one leachate sample collected from MW-125P) and were analyzed for TCL VOCs which resulted in 58 total samples. The samples were collected from wells throughout the Former Operational Areas and Former Bryant Mill Pond. VOCs were identified in 20 of the monitoring wells at the site. One groundwater sample collected from monitoring well MW-114 had concentrations of tetrachloroethene that exceeded the screening criteria. This data suggest that VOCs, although present in the groundwater at the site, do not pose a concern, especially when considered in conjunction with site soil data. Five of the 33 VOCs on the TCL at the time of sampling were detected in the groundwater samples and six VOCs were detected in the leachate samples during 1993 (single sampling event). One or more VOCs were detected in 20 of the 57 groundwater samples and in the one leachate sample. The detected VOCs in the groundwater sample included (in order of decreasing frequency of detection): benzene (7 samples), toluene (6 samples), tetrachloroethene (3 samples), 1,1,1-trichloroethane (2 samples), and methylene chloride (2 samples). TCL VOCs detected in the single sample of leachate (i.e., MW-125P) consisted of benzene, 2-butanone, carbon disulfide, ethylbenzene, toluene, and xylenes (Table 4-4C). Figure 4-4C presents the location of VOC detections and single exceedance for the 1993 and 2003 sampling events.

Groundwater samples from two monitoring wells (MW-215 and MW-216) were collected during the 2003 sampling event (which resulted in 3 samples) and analyzed for TCL VOCs. These wells were located donwgradient of the Former Type III Landfill, an area where a variety of wastes were disposed of in the past. Acetone was detected in the three samples but below its corresponding screening criteria (Table 4-4C). These data are consistent with previous sections of the report that identify the nature of VOC contaminants as being present at the site at low concentrations. The potential for VOCs to affect the partitioning of PCBs has not been evaluated. Figure 4-4C presents the location of VOC detections and single exceedance for the 1993 and 2003 sampling events.

SVOCs

1993 Data

Groundwater from fifty-one monitoring wells and one leachate sample were collected during this single sampling event (which resulted in 58 samples) and analyzed for TCL SVOCs. The samples were collected from wells throughout the Former Operational Areas and the Former Bryant Mill Pond. SVOCs were identified in 8 of the monitoring wells at the site. One groundwater sample collected from monitoring well MW-125P in the Former Monarch HRDL had concentrations of 4-methylphenol that exceeded the screening criteria. This data suggest that SVOCs were present in the groundwater at the time of sampling at concentrations below the screening criteria, with one exception. The SVOC groundwater impact appears to be much less extensive than the SVOCs in soil at the site. However the SVOCs in the soil appear to be a source of low concentration SVOC impact to the groundwater. Six SVOCs on the TCL at the time of sampling were detected in the groundwater samples and one SVOC was detected in the leachate samples during 1993. The detected SVOCs include (in order of decreasing frequency): 4-methylphenol (4 samples), phenol (1 sample), 2-methylnaphthalene (1 sample), di-n-butylphthlate (1 sample), diethyl phthalate (1 sample), 2-methylnaphthalene (1 sample), 2-methylphenol (1 sample), and naphthalene (1 sample) as shown in Table 4-4C. The single sampling point having exceedances of TCL SVOCs, is presented in Table 4-4D. Figure 4-4D presents the location of SVOC detections and single exceedance for the 1993 and 2003 sampling events.

2003 Data

Groundwater samples from two monitoring wells (MW-215 and MW-216) were collected during the 2003 sampling event (3 samples) and analyzed for TCL SVOCs. These wells were located downgradient of the Former Type III Landfill, an area where a variety of wastes were disposed of in the past. Phenol was detected in two of the three samples but below its corresponding screening criteria (see Table 4-4C). When these data are considered with the earlier data, it suggests that SVOCs remain present at detectable concentrations in the groundwater at the site. The SVOC groundwater impact appears to be much less extensive than the SVOCs in soil at the site. Figure 4-4D presents the location of the combined SVOC detections and single exceedance for the 1993 and 2003 sampling events.

Pesticides

1993 Data

Groundwater from fifty-one monitoring wells and one leachate sample were collected during this single sampling event (which resulted in 58 samples) and analyzed for TCL pesticides. The samples were collected from wells throughout the Former Operational Areas and the Former Bryant Mill Pond. Of the 21 pesticides on the TCL, none were detected in samples of groundwater. One pesticide, alpha-BHC, was detected in the leachate sample collected from monitoring well MW-125P (Table 4-4C). This data suggest that pesticides were not present in the groundwater at the time of sampling which is consistent with the soil and sediment data. The location of monitor well MW-125P is shown in Figure 8.

TAL Inorganics

1993 Data

Groundwater from 51 monitoring wells and one leachate were collected during this single sampling event (which resulted in 57 groundwater samples and one leachate sample) for unfiltered and filtered analyses of TCL Inorganics parameters. The samples were collected from wells throughout the Former Operational Areas and the Former Bryant Mill Pond. Of the parameters indicated below in filtered samples, aluminum, arsenic, cadmium, iron, manganese, mercury, nickel, sodium, vanadium, and zinc were detected above their respective screening criteria. This data suggest that TAL constituents were present throughout the site groundwater at the time of sampling at concentrations above the screening criteria. The TAL constituent groundwater impact appears to be of a similar nature to the soil impact identified at the site. The following TAL and total dissolved solids (TDS) constituents were detected in the filtered groundwater samples, listed in order of decreasing frequency: TDS (57 samples), barium (57 samples), calcium (57 samples), magnesium (57 samples), sodium (57 samples), manganese (57 samples), iron (57 samples), potassium (53 samples), zinc (51 samples), arsenic (48 samples), nickel (37 samples), selenium (19 samples), lead (14 samples), cobalt (9 samples), chromium (6 samples), cadmium (4 samples), aluminum (2 samples), beryllium (2 samples), mercury (2 samples), and vanadium (1 sample). Subsequently, the following TAL constituents were detected in the unfiltered groundwater samples, listed in order of decreasing frequency: barium (57 samples), calcium (57 samples), magnesium (57 samples), sodium (57 samples), manganese (57 samples), iron (57 samples), potassium (55 samples), zinc (53 samples), arsenic (43 samples), nickel (30 samples), lead (26 samples), chromium (19 samples), selenium (12 samples), aluminum (12 samples), cyanide (6 samples), beryllium (4 samples), copper (4 samples), cobalt (3 samples), mercury (3 samples), and vanadium (2 samples) as shown in Table 4-4C. The maximum detected concentration of these parameters were lower in the filtered samples as compared to the unfiltered samples. Cadmium was detected in the filtered sample but not in the unfiltered samples while the reverse was true for the presence of copper and cyanide in the unfiltered samples (i.e. detected) as compared to the filtered samples. Of the parameters indicated above for unfiltered samples, aluminum, arsenic, chromium, cyanide, iron, lead, manganese, mercury, nickel, sodium, vanadium, and zinc were detected above their respective screening criteria as shown in Table 4-4D which appears to be a site wide concern. Table 4-3C(CD) summarizes the TAL constituents detected in each filtered and unfiltered groundwater samples collected. A figure presenting the 1993 inorganic analytical results is not included in this report.

The single filtered leachate (monitoring well MW-125P) indicated the presence of TDS, aluminum, arsenic, barium, calcium, chromium, iron, magnesium, manganese, nickel, potassium, and sodium. The unfiltered leachate sample indicated the presence of the same parameters in the filtered sample plus mercury, vanadium, and zinc as shown in Table 4-4C.

It should be recognized, however, that where mercury was detected at concentrations exceeding the screening criteria in 1993, these same locations were not analyzed during the 2002 and 2003 sampling events.

2002 Data

Unfiltered groundwater samples from 38 monitoring wells and one unfiltered leachate sample from gas vent GV-10 were collected during this 2002 single sampling event (which resulted in 42 groundwater samples and one leachate sample) for analyses of TCL Inorganics parameters. The samples were collected from wells throughout the Former Operational Areas and the Former Bryant Mill Pond. Of the parameters indicated below, aluminum, arsenic, barium, chromium, cyanide, iron, mercury, manganese, nickel, silver, sodium, vanadium, and zinc were detected above their respective screening criteria. This data suggest that TAL constituents were present throughout the site groundwater at the time of sampling at concentrations above the screening criteria. The TAL constituent groundwater impact appears to be of a similar nature to the soil impact identified at the site.

The following TAL constituents were detected in the groundwater samples, listed in order of decreasing frequency: barium (42 samples), calcium (42 samples), magnesium (42 samples), potassium (42 samples), sodium (42 samples), manganese (41 samples), iron (41 samples), arsenic (22 samples), zinc (16 samples), copper (14 samples), aluminum (13 samples), nickel (6 samples), cadmium (5 samples), cobalt (5 samples), vanadium (4 samples), chromium (2 samples), lead (14 samples), selenium (1 sample), silver (1 sample), cyanide (1 sample), and antimony (1 sample) as shown in Table 4-4C. Of the parameters indicated above, aluminum, arsenic, barium, chromium, cyanide, iron, mercury, manganese, nickel, silver, sodium, vanadium, and zinc were detected above their respective screening criteria (as shown in Table 4-4D). Table 4-3C(CD) summarizes the TAL constituents detected in the groundwater samples collected. Figure 4-4E presents the location where manganese exceeded its screening criteria for 2002 and 2003 sampling events. Figure 4-4F presents the locations where arsenic exceeded its screening criteria for 2002 and 2003 sampling events. Figure 4-4G presents the location where iron exceeded its screening criteria for 2002 and 2003 sampling events. Figure 4-4H presents the locations where all other TAL constituents, excluding manganese, arsenic, and iron, exceeded their screening criteria for the 2002 and 2003 sampling events.

The single leachate sample (from gas vent GV-10) indicated the presence of aluminum, arsenic, barium, calcium, chromium, cobalt, cyanide, iron, magnesium, manganese, mercury, nickel, potassium, selenium, sodium, and vanadium as shown in Table 4-4C. The concentrations of these parameters above their respective screening criteria are shown in Table 4-4D.

2003 Data

Unfiltered groundwater samples were collected from 27 monitoring wells during the 2003 single sampling event (which resulted in 31 groundwater samples) for analyses of TCL Inorganics parameters. Again, the samples were collected from wells throughout the Former Operational Areas and the Former Bryant Mill Pond. Of the parameters indicated below, aluminum, arsenic, barium, cyanide, iron, lead, manganese, nickel, sodium, and zinc were detected above their respective screening criteria. This data suggest that TAL constituents are present throughout the site groundwater at concentrations above the screening criteria. The TAL constituent groundwater impact appears to be of a similar nature to the soil impact identified at the site.

The following TAL constituents were detected in the groundwater samples, listed in order of decreasing frequency: barium (31 samples), calcium (31 samples), magnesium (31 samples), manganese (31 samples), potassium (31 samples), sodium (31 samples), iron (29 samples), zinc (12 samples), copper (11 samples), arsenic (11 samples), nickel (10 samples), lead (8 samples), vanadium (5 samples), chromium (5 samples), aluminum (5 samples), cobalt (3 samples), cyanide (3 samples) as shown in Table 4-4C. Of the parameters indicated above, aluminum, arsenic, barium, cyanide, iron, lead, manganese, nickel, sodium, and zinc were detected above their respective screening criteria (as shown in Table 4-4D) appear to be site wide concerns. Table 4-3C(CD) summarizes the TAL constituents detected in the groundwater samples collected. Figure 4-4E presents the location where manganese exceeded its screening criteria for 2002 and 2003 sampling events. Figure 4-4F presents the locations where arsenic exceeded its screening criteria for 2002 and 2003 sampling events. Figure 4-4G presents the location where iron exceeded its screening criteria for 2002 and 2003 sampling events. Figure 4-4H presents the locations where all other TAL constituents, excluding manganese, arsenic, and iron, exceeded their screening criteria for the 2002 and 2003 sampling events.

Based upon the data presented above, the concentration of zinc appears to be elevated in groundwater samples at the site and it appears to be related to well construction (galvanized) materials. As discussed in a letter to the MDEQ dated August 13, 1997 (Brown, 1997), elevated concentrations of zinc were associated with groundwater samples collected from pre-RI wells constructed with a galvanized pipe riser.

Although only two leachate samples are available for comparison, there appears to be hydrochemical differences with groundwater samples. Concentrations of aluminum and vanadium are two orders of magnitude higher in leachate than in groundwater. Although, aluminum is at higher concentrations in the leachate than in the groundwater, it is well known to dissolve under the lower pH conditions of the leachate. Concentrations of potassium, nickel, and cobalt also appear to be up to two orders of magnitude higher in leachate than in groundwater, and are also a likely result of the lower pH conditions in the leachate.

4.4.1.3 General Water Quality Parameters in Groundwater and Leachate Samples

A total of 148 discrete samples of groundwater and leachate were collected and analyzed for general water quality parameters during four phases of investigation – September-October 1993, December 1995, October-November 2002, and April-May 2003. During the October-November 2002 sampling event, two additional groundwater samples collected from GV-10 and MW-125P were later characterized as leachate. Those samples were not collected to assess the nature and extent of constituents at the Site; instead, they were collected to identify a characteristic hydrochemical signature for leachate. Groundwater or leachate samples were not analyzed for general water quality parameters during the 1997, 1998, and 2000-2001 sampling events.

The analytical results of these samples are presented in Table 4-4A(CD). The frequency of detection and range of detected concentrations of general groundwater quality parameters are presented in Table 4-4E. Table 4-4F presents the water quality parameters that exceeded their respective screening criteria. The location of any sampling point having an exceedance of a water quality parameter is shown in Figure 4-4I. Major ions such as sodium, potassium, calcium, and magnesium, which could be considered general water quality parameters, were analyzed separately along with other TAL constituents (see Sections 4.4.1.3).

1993 Data

During the 1993 sampling event (single sampling event), 51 monitoring well locations (which resulted in 57 groundwater samples) and one leachate sample from well MW-125P were collected for analyses. The general water quality parameters analyzed during this sampling event included total and bicarbonate alkalinity, chloride, sulfate, nitrogen (combined concentrations of nitrate and nitrite), TSS, chemical oxygen demand (COD), and TOC. Only chloride and nitrate/nitrite parameters exceeded their respectively screening criteria. These exceedances were from both shallow and deep wells generally located in the southern portion of the Former Bryant HRDL-FRDL and the Monarch HRDL.

1995 Data

Only one groundwater sample was collected from monitoring well MW-124A during this period. The sample was analyzed for TSS only and the concentration did not exceed its screening criteria.

2002 Data

During this sampling single event, water samples were collected from 38 monitoring wells (which resulted in 42 groundwater samples) and one leachate sample. The general water quality parameters analyzed during the sampling event consisted of alkalinity (carbonate, bicarbonate, and hydroxide), chloride, sulfate, nitrogen (nitrate/nitrite), and TSS. Chloride was the only parameter that exceeded it corresponding screening criteria from nine groundwater samples and one leachate sample. Generally, these exceedances were located in the southern portion of the Former Bryant HRDL-FRDL and the Monarch HRDL.

2003 Data

Samples were collected from 40 monitoring wells (which resulted in 46 groundwater samples) during this single sampling event. The general water quality parameters analyzed during this sampling event consisted of alkalinity (carbonate, bicarbonate, and hydroxide), chloride, sulfate, nitrogen (nitrate/nitrite), and TSS. Chloride was the only parameter that exceeded it corresponding screening criteria from seven samples. Generally, these exceedances were located in the southern portion of the Former Bryant HRDL-FRDL and the Monarch HRDL from both shallow and deep wells. However, the groundwater sample collected from monitoring well MW-6 located on the Conrail property had one of these chloride exceedances.

4.4.2 Groundwater Seep Sample Analytical Results

Groundwater seeps have long been a feature at the OU and are typical of such regional groundwater discharge zones as Portage Creek. A spring (commonly referred to within this RI as a groundwater seep) is a feature that exists when groundwater is under sufficient hydrostatic pressure enough to rise above the aquifer containing it. The flow of groundwater from some of the seeps at OU1 appears to be effected by water level (i.e. seasonally affected) and others are active throughout the year. The near surface groundwater velocities at the seeps are typically strong enough to result in visible transport of material (as clearly evidenced at seeps SP-254, SP-299, Seep-A, Seep-B, Seep-G, Seep-H, and Seep-J). These areas of increased flow result in surface flow and erosion which carries particulates (i.e., soils/sediments) toward and into Portage Creek. Transport from the seeps to Portage Creek can be observed and is most obvious at seeps with greater discharge. The particulates transported by the springs/seeps will include those associated with the PCB contaminant.

Groundwater seeps results are discussed separately from the groundwater and leachate discussion due to the distinct difference this transport path represents (see Section 4.4.1 for the Groundwater/Leachate discussion). The groundwater seeps at the site are part of a more discrete transport path which is difficult to evaluate except at the point where the groundwater expresses itself at the surface. The contaminant loading associated with the groundwater discharging at the seeps are of particular interest due to the high flow rates (relative to typical groundwater discharge).

Groundwater seeps were sampled in 1993, 2000, 2002, and 2003 to characterize groundwater seep quality at the site. The technique for groundwater seep sampling in 1993 (where just one location, Rivulet 2 [also identified as SP-299], was sampled) and 2000 (where groundwater seeps A through E and G through K were sampled) differed from that used in 2002 and 2003. In 1993, groundwater seep sampling was conducted by placing a sampling container directly into the flowing groundwater seep. In 2000, groundwater seep sampling was conducted by excavating a small depression in the middle of each groundwater seep utilizing a shovel. Once the flow of water from the groundwater seep appeared clear and free of solids, a sample container was dipped into the depression and a water sample was collected. In 2002 and 2003, in order to improve the sampling procedure for the groundwater seeps, temporary monitoring wells were constructed at the groundwater seep locations as described in section 1.3.1 in Appendix C of this report. Unfiltered groundwater seep water samples were collected using a peristaltic pump in temporary monitoring wells that were installed at the groundwater seep locations. The groundwater seep samples were analyzed for TCL, TAL, and/or general water quality parameters. The details and results of groundwater seep sampling conducted in 1993 are reported in the groundwater analytical data discussions in Section 3.3 of *Technical Memorandum 7* (BBL, 1997c). The analytical results and QA/QC review reports for groundwater seep samples collected in 2002 and 2003 are included in Appendix L.

Table 2-7 presents a summary of the groundwater seep water samples submitted for chemical analysis during the RI. The constituent-specific analytical results for all the groundwater seep samples are presented in Tables 4-4A(CD) through 4-4D(CD) and Appendix MDEQ - B. The frequency of detection and range of concentrations of chemicals detected in groundwater seep samples are summarized by study area in Tables 4-4G, Table 4-4I, and Table 4-4K. The results of the 2002 and 2003 sample activities are discussed below. Due to the sampling methodology used at the groundwater seeps in 1993 and 2000, the PCB results are not discussed in Section 4.4.2.1, but the data are presented in Table 4-4A(CD) through Table 4-4D(CD) and Appendix MDEQ - B.

Screening Criteria

For the purposes of developing the contaminants of concern for the OU, applicable media are compared to the MDEQ generic criteria for groundwater. As an initial screening, all laboratory results were compared to Table 1 of RRD Operational Memorandum No. 1, Part 201Generic Cleanup Criteria and Screening Levels (12/23/06) of Part 201.. Determination of the applicability of cleanup criteria for groundwater seeps at the Allied OU will be made by the USEPA, in consultation with the MDEQ, during review of ARARs in the FS.

4.4.2.1 PCBs in Groundwater Seep Samples

Groundwater seep samples for PCB analysis were collected in 1993, 2000, 2002, and 2003. As indicated above, samples collected during the 1993 and 2000 sampling events will not be discussed due to the sampling methodology used to collect these samples but these data are presented in Tables 4-4A(CD) through 4-4D(CD) and Appendix MDEQ - B. For the purposes of simplifying the data, sampling events conducted in 2002 and 2003 will be discussed as a single event.

2002-2003 Data

During the 2002 there was one sampling event that consisted of the collection of 42 samples from all groundwater seep locations that were identified for sampling. This included the collection of 20 groundwater seep samples (including duplicates at SP-I, SP-235) by MHLLC and 20 split samples collected by MDEQ. 2003 consisted of the collection of 29 samples from 14 groundwater seep locations (excluding SP-A, SP-D, SP-E, SP-G, SP-I, SP-M from the 2002 list). This included the collection of 14 groundwater seep samples (including one duplicate at SP-242) by MHLLC and 14 split samples collected by MDEQ. The two years of sampling activity resulted in the analyses of 71 samples from the groundwater seep locations. The groundwater seeps generally occur near the perimeter of the Former Operational Areas along Portage Creek. The groundwater seeps that produced samples with detectable levels of PCBs were sporadically located along the sheetpile (at SP-611, SP-508, and SP-242) or were located near the northwest corner of the Former Type III landfill (at SP-G, SP-H, and SP-J). The groundwater seeps with PCBs concentrations in excess of the screening criteria were concentrated near the northwest corner of the Former Type III landfill at groundwater seeps SP-H and SP-G. The groundwater seeps that have been identified and sampled at the site were generally exposed following excavation during the Removal Action and IRM. Other groundwater seeps that were not made readily apparent by the Removal Action and IRM activities, likely exist at the site.

The frequency of detection and range of detected concentrations of PCB values are presented in Table 4-4G. Table 4-4H presents the locations of the PCB exceedances during this period. PCBs were detected in groundwater seep samples collected from SP-G (0.87 μg/L by MHLLC, 1.1 μg/L by MDEQ; in 2002), SP-H (1.9 and 2.8 μg/L by MHLLC in 2002 and 2003, respectively; 2.9 μg/L and 1.4 μg/L by MDEQ in 2002 and 2003 respectively), SP-J (0.088 and 0.055 μg/L by MHLLC in 2002 and 2003, respectively; 0.087 μg/L and 0.065 μg/L by MDEQ in 2002 and 2003, respectively), SP-242 (0.052 μg/L and non-detect by MHLLC in 2002 and 2003, respectively; 0.083 μg/L and 0.012 μg/L by MDEQ in 2002 and 2003, respectively), SP-508 (0.017 µg/L by MDEQ in 2003), and SP-611 (non-detect at 0.051 μg/L and 0.052 μg/L by MHLLC in 2002 and 2003, respectively; 0.041 μg/L by MDEQ in 2003). The sample locations and exceedances of PCBs are present in Figure 4-4J.

4.4.2.2 TCL VOCs, SVOCs, Pesticides, and TAL Inorganic in Groundwater Seep Samples

Groundwater seep samples were collected from five locations in the Former Bryant Mill Pond for laboratory analysis of VOCs, SVOCs, pesticides, and TAL inorganics during sampling phases conducted in September 1993 (one groundwater seep sample) and December 2002 (four groundwater seep samples). Table 4-4B(CD) presents the analytical results for each of the five groundwater seep samples collected by MHLLC. The MDEQ collected splits of some of the groundwater seep samples and analyzed them for TCL VOCs and SVOCs. TCL pesticides were not analyzed as part of the groundwater seep analytical program. A summary of the analytical results for the split samples is presented in Appendix MDEQ - B.

VOCs

1993 Data

During the 1993 sampling event, one sample was analyzed that was collected from one location (Rivulet 2). Analysis of this sample did not indicate the presence of any VOCs.

2002 Data

While excavating soils to install the temporary wells for these groundwater seeps, an oily sheen was observed to be floating on the water table. Based on this observation, the water samples collected in 2002 from groundwater seeps SP-G, SP-H, SP-I, and SP-J were analyzed for CLP VOCs and SVOCs.

Nine samples were analyzed from four groundwater seep locations. VOCs were detected in two groundwater seep samples from one location (SP-I) at concentrations below the screening criteria. These results are consistent with previous sections of the report that identify the nature of VOC contaminants as being present at the site at low concentrations. The potential for VOCs to affect the partitioning of PCBs has not been evaluated.

The frequency of detection and range of detected concentrations of values is presented in Table 4-4I. One VOC (toluene) was detected in two of the groundwater seep samples (sample and sample duplicate) located from one location (SP-I) but did not exceed its respective screening criteria. Trace concentrations of polar VOCs were also detected in nearby groundwater samples collected from MW-215 and MW-216.

SVOCs

1993 Data

During the 1993 sampling event, one sample was collected from one location (Rivulet 2) and analyzed for SVOCs. Analysis of this sample did not indicate the presence of any SVOCs.

2002 Data

One sampling event was conducted in 2002 in which nine samples were analyzed from four groundwater seep locations. SVOCs were detected in two groundwater seep samples from one location (SP-I) at concentrations below the screening criteria. When these data are considered with the earlier data, they suggest that SVOCs remain present at detectable concentrations in the groundwater at the site. The SVOC groundwater impact appears to be much less extensive than the SVOCs in soil at the site.

The frequency of detection and range of detected concentrations of values is presented in Table 4-4I. One SVOC (4-methylphenol) was detected in two of the groundwater seep samples (sample and sample duplicate) located from one location (SP-I) but did not exceed its respective screening criteria.

TAL Inorganics

1993 Data

During the 1993 sampling event, one sample was collected from one location (Rivulet 2, as known as SP-299) and analyzed for TAL Inorganics. The frequency of detection and range of detected concentrations of TAL Inorganics is presented in Table 4-4I. The following inorganics were detected in this sample: barium, calcium, iron, magnesium, manganese, potassium, and sodium. Concentrations of iron and manganese exceeded their respective screening criteria as shown in Table 4-4J. The sample location of these exceedances are presented in Figure 4-4K.

2000 Data

One sampling event was conducted in 2000 in which 12 samples were analyzed from 10 groundwater seep locations. The samples were collected from groundwater seep wells throughout the Former Operational Areas and the Former Bryant Mill Pond. All the parameters indicated below were detected above their respective screening criteria. This data suggest that TAL constituents were present in groundwater seep samples at the site at concentrations above the screening criteria. This impact appears to be of a similar nature to the previous groundwater and soil TAL constituent exceedances identified at the site.

The frequency of detection and range of detected concentrations of inorganic values is presented in Table 4-4I. The following TAL constituents were detected in the groundwater samples, listed in order of decreasing frequency: barium (12 samples), zinc (12 samples), lead (7 samples), arsenic (6 samples), mercury (4 samples), copper (3 samples), and chromium (2 samples). All the detected inorganics exceeded their respective screening criteria as shown in Table 4-4J. The sample locations of these exceedances are presented in Figure 4-4K.

2002 Data

During the 2002 single sampling event, 22 samples were analyzed from 20 groundwater seep locations. The samples were collected from groundwater seep wells throughout the Former Operational Areas and the Former Bryant Mill Pond. Several of the parameters indicated below were detected above their respective screening criteria. This impact appears to be of a similar nature to the previous groundwater seep, groundwater, and soil TAL constituent exceedances identified at the site.

The following TAL constituents were detected in the groundwater samples, listed in order of decreasing frequency: barium (22 samples), calcium (22 samples), magnesium (22 samples), manganese (22 samples), potassium (22 samples), sodium (22 samples), iron (20 samples), zinc (8 samples), arsenic (8 samples), nickel (7 samples), aluminum (6 samples), vanadium (5 samples), selenium (4 samples), cobalt (3 samples), chromium (2 samples), copper (1 sample), cyanide (1 sample), and lead (1 sample) as shown in Table 4-4I. Aluminum, arsenic, barium, cyanide, iron, manganese, selenium, and vanadium were detected above their respective screening criteria as shown in Table 4-4J. The sample locations of these exceedances are presented in Figure 4-4K.

2003 Data

In a 2003 single sampling event, 15 samples were analyzed from 14 groundwater seep locations. The samples were collected from groundwater seep wells throughout the Former Operational Areas and the Former Bryant Mill Pond. Several of the parameters indicated below were detected above their respective screening criteria. This impact appears to be of a similar nature to the previous groundwater seep, groundwater, and soil TAL constituent exceedances identified at the site.

The following TAL constituents were detected in the groundwater samples, listed in order of decreasing frequency: barium (15 samples), calcium (15 samples), magnesium (15 samples), manganese (15 samples), potassium (15 samples), sodium (15 samples), iron (14 samples), arsenic (4 samples), antimony (3 samples), cobalt (3 samples), lead (3 samples), nickel (3 samples), selenium (2 samples), cyanide (2 samples), zinc (1 sample), copper (1 sample), chromium (1 sample), and aluminum (1 sample) as shown in Table 4-4I. Arsenic, barium, cyanide, iron, and manganese were detected above their respective screening criteria as shown in Table 4-4J. The sample locations of these exceedances are presented in Figure 4-4K.

4.4.2.3 General Water Quality Parameters in Groundwater Seep Samples

Forty-seven groundwater seep samples were analyzed for one or more general water quality parameters during sampling phases conducted in September 1993, May 2000, December 2002, and April-May 2003 sampling events.

The general water quality parameters for which the 1993 samples were analyzed include bicarbonate alkalinity, chloride, sulfate, nitrogen (combined concentrations of nitrate and nitrite), TSS, COD, and TOC. The samples collected during the 2000 and 2002 sampling events were only analyzed for TSS. The general water quality parameters for the 2003 sampling event were analyzed consisted of alkalinity (carbonate, bicarbonate, hydroxide, and total), chloride, sulfate, nitrogen (nitrate/nitrite), and TSS. Major ions such as sodium, potassium, calcium, and magnesium, which could be considered general water quality parameters, were analyzed separately along with other TAL constituents (see Sections 4.4.2.2).

The analytical results of these samples are presented in Table 4-4A(CD). The frequency of detection and range of detected concentrations of general groundwater seep quality parameters are presented in Table 4-4K. Table 4-4L presents the water quality parameters that exceeded their respective screening criteria. The location of any sampling point having an exceedance of a water quality parameter is shown in Figure 4-4L. Major ions such as sodium, potassium, calcium, and magnesium, which could be considered general water quality parameters, were analyzed separately along with other TAL constituents (see Section 4.4.2.2.)

1993 Data

In 1993, one sampling event was performed that included the analysis of one water sample collected from one groundwater seep location. The frequency of detection and range of detected concentrations of water quality parameters is presented in Table 4-4K. The following parameters were detected in this sample: bicarbonate alkalinity, chloride, sulfate, TSS, COD, and TOC but not at levels that exceeded their respective screening criteria.

2000 Data

One sampling event was performed during this period that included the analysis of 10 water samples collected from 10 groundwater seep locations. These samples were only analyzed for TSS which was detected in all samples. The frequency of detection and range of detected concentrations of TSS values is presented in Table 4-4K.

2002 Data

One sampling event was performed during 2002. During this sampling event, 21 water samples for TSS analysis were collected from 20 groundwater seep locations. The frequency of detection and range of detected concentrations of TSS values is presented in Table 4-4K.

2003 Data

During 2003, only one sampling event was performed. 15 water samples were analyzed that were collected from 14 groundwater seep locations. The frequency of detection and range of detected concentrations of values is presented in Table 4-4K. Only two water samples collected from two locations (SP-B and SP-O) indicated the exceedances of chloride (Table 4-4L). The location of these exceedances is shown in Figure 4-4L.

4.4.3 PCBs in Other Groundwater Samples

During the period from 2002 to 2003, MDEQ collect groundwater samples from MHLLC installed permanent and temporary sumps and from groundwater leakage through sheet pile joints. A summary of the analytical results for these samples is presented in Appendix MDEQ - B. The sampling results discussed here for "other groundwater samples" do not substantively advance the understanding of the nature and extent of PCBs at this site.

2002 Data

During 2002, MDEQ collected eight water samples from five different permanent sump locations and four samples from four different temporary sump locations. The samples obtained from the permanent sump locations were collected by pumping down the water level within the sump below the inlet of the French drains and allowing the drains to free flow for a short period of time before the sample was collected. Samples obtained from the temporary sumps were collected from within the sump itself after the pump was turned off the previous day to allow the solids within the water column to settle prior to collecting the groundwater sample. All the water samples collected from the permanent sumps indicated detectable concentrations of PCBs but only five samples had detectable concentrations above its corresponding screening criteria. Only one sample collected from the temporary sumps indicated detectable concentrations of PCBs but the value did not exceed its screening criteria. The frequency of detection and range of detected concentrations of PCB values from these sumps is presented in Table 4-4M. Table 4-4N presents the locations of the PCB exceedances from these sumps during this period.

2003 Data

During 2003, MDEQ collected three water samples from three different areas along the sheet pile wall that were leaking. Sample bottles were filled directly from the leak areas. All collected samples indicated the presence of PCBs but only one sample exceeded its screening criteria. The frequency of detection and range of detected concentrations of PCB values from these leaking sheet pile areas is presented in Table 4-4M. Table 4-4N presents the locations of the PCB exceedances from these leaking areas during this period.

4.5 Surface Water Investigation

Surface water samples were collected at the Allied OU as well as from upstream and downstream locations during several investigations conducted for different purposes. Portage Creek surface water investigations were conducted for the Allied OU RI in 1993, 1994, 1997, and 2003, to characterize the nature and extent of regulated constituents in surface water during different flow conditions. Other surface water samples were collected during the Removal Action at the Former Bryant Mill Pond in 1998 and 1999 for the separate purpose of monitoring PCB concentrations during removal activities. The Removal Action surface water monitoring data are summarized in Table E-1 of Appendix E, and are not used to describe the current site conditions. The 1993 and 1994 samples were analyzed for PCB, TAL Inorganics and TCL VOCs and SVOCs. The 1997 and 1998 samples were analyzed for PCBs and TSS, while the 1999 samples were analyzed for PCBs. In 2003, a single sample was collected from Portage Creek and analyzed for general chemistry parameters in order to obtain a hydrochemical signature at a location of Portage Creek (SG-1) adjacent to the Bryant HRDL and FRDLs to which samples of groundwater, groundwater seeps, and leachate could be compared.

Additionally, in 1999 the MDEQ initiated a LTM Program, in part, to assess the surface water and biota in Portage Creek and other areas of the Kalamazoo River Superfund Site. Analytical results for surface water samples collected from Portage Creek by the MDEQ subsequent to the Removal Action provide the most recent comprehensive data set available for the Allied OU. These MDEQ data and the previous surface water characterization data obtained by MHLLC for the RI are discussed in the following subsections.

Potentially Applicable Criteria

The MDEQ has developed a process to establish surface water quality criteria (within Part 4 Water Quality Standards, of Part 31 Water Resources Protection, of the NREPA, 1994, P.A. 451, as amended), commonly referred to as the Michigan Rule 57 criteria, based on assumed exposure scenarios and generic exposure factors. These criteria are intended to represent threshold concentrations of chemical constituents (i.e., exposure to concentrations above these thresholds are assumed to present an unacceptable potential threat to human or ecological health) (MAC 323.1057). The available Rule 57 surface water criteria for PCBs are summarized in the table on the next page.

Michigan Rule 57 Criteria for PCBs in Surface Water

Wildlife Value (µg/L)[1]	Human Cancer Value – Drinking Water (µg/L)[2]	Human Cancer Value Non-Drinking Water (µg/L)[3]
0.00012	0.000026	0.000026

Source: MAC 323.1041
[1]Estimated maximum ambient water concentration at which adverse effects are not likely to result in population-level impacts to mammalian and avian wildlife populations from lifetime exposure through drinking water and aquatic food supply
[2]Estimated maximum ambient water concentration of a substance at which a lifetime of exposure from drinking the water, consuming fish from the water, and conducting water-related recreation activities will represent a plausible upper bound risk of contracting cancer of 1 in 100,000.
[3]Estimated maximum ambient water concentration of a substance at which a lifetime of exposure from consuming fish from the water and conducting water-related recreation activities will represent a plausible upper bound risk of contracting cancer of 1 in 100,000.

The MDEQ also has derived site-specific surface water PCB criteria intended to be protective of ecological receptors that are most sensitive to PCBs. The criteria derived from the NOEL/LOEL thresholds for PCB concentrations in surface water are 1.6 and 1.97 nanograms per liter (ng/L), respectively (CDM, 2003a and b). The MDEQ considers both the Michigan Rule 57 criteria and the site-specific surface water criteria to be potentially applicable at the Allied OU. Determination of the applicability of cleanup criteria for surface water and other environmental media at the Allied OU will be made by the USEPA, in consultation with the MDEQ, during review of ARARs in the FS.

4.5.1 Site Surface Water Investigation

Surface water samples were collected from sampling locations SW-P1, SW-P2, and SG-1 in Portage Creek (shown on Figure 11) during sampling events conducted in 1993, 1994, 1997, and 2003 to characterize the nature and extent of regulated constituents in surface water during different flow conditions at the Allied OU. During these sampling events 90 surface water samples were analyzed for general water quality parameters (alkalinity, chloride, nitrogen, sulfate, and/or TSS); four samples were analyzed for TCL VOCs, SVOCs, and pesticides; five samples were analyzed for the TAL inorganic parameters; and 127 samples were analyzed for PCBs. The analytical results for the surface water samples collected in 1993, 1994, and 1997 are discussed in Section 3.2.1 of *Technical Memorandum 11* (BBL, 2000a). The analytical data QA/QC review and data review report for the surface water samples are included in Appendix P. Table 2-9 presents a summary of the surface water samples submitted for chemical analysis for the RI. The analytical results for detected general water quality parameters, TAL inorganic constituents, and PCBs for surface water samples collected by MHLLC for the RI are presented in Tables 4-6A(CD), 4-6B(CD), and 4-6C(CD), respectively. The single surface water sample collected in 2003 was analyzed for general chemistry and TAL inorganics and was not analyzed for PCBs. The analytical data QA/QC review and data review report for the single surface water sample is included in Appendix P. The analytical results for detected general water quality parameters and TAL inorganic constituents for the surface water sample collected by MHLLC are presented in Tables 4-6A(CD) and 4-6B(CD), respectively. A summary of the frequency of detection and range of detected concentrations of general water quality parameters and TAL constituents are presented in Table 4-5C. Table 4-5D presents a summary of exceedances in TAL constituents. Two inorganics, aluminum and manganese exceeded screening criteria in the one sample collected in 2003 from SG-1.

4.5.2 MDEQ Long-Term Surface Water Monitoring Program

The LTM Program for surface water included sampling stations along Portage Creek, located upstream, downstream, and within the Allied OU. The sampling locations that are pertinent to the RI and shown in Figure 11 include:

- Cork Street (the upstream end of the Allied OU);
- Alcott Street, located 1 mile downstream of Cork Street (the downstream end of the Allied OU); and
- Bryant Street, located 1.1 mile downstream of Cork Street.

To date, data are available for sampling events conducted from August 1999 to April 2006. The samples of surface water were submitted to the MDEQ's laboratory for analysis of TSS and PCBs, and the available results are included in Appendix MDEQ - B for Cork, Alcott, and Bryant Street locations. As the Alcott Street sampling location was replaced by the Bryant Street location (due to ease of access) after 2000, the Alcott Street data are not discussed below but are in presented in Appendix MDEQ - B for review.

Table 4-5A presents the frequency of detection and range of detected concentrations of PCBs and Table 4-5B presents the exceedances of PCB screening criteria. Due to the low screening criteria value (0.000026 parts per billion[ppb]), if PCBs are detected in a sample, it will exceed the criteria. Since 2000, a total of 16 samples exceeded the screening criteria at Cork Street, while 29 samples exceeded at Bryant Street. Average PCB concentrations during this period increase from upstream (0.015 μg/L at Cork Street) to downstream locations (0.031 μg/L at Alcott/Bryant Street) by a factor of two. Thus, the site still appears to be contributing PCBs to

Portage Creek surface water. The frequency of detection and range of detected concentrations of TSS from Cork and Bryant Street from 2000 to 2006 are presented in Table 4-5C (in order to provide a post-Removal Action review only, the 1999 data are not presented in the tables but are provided in Appendix MDEQ – B).

4.6 Biota Investigation

As part of a larger effort conducted for the Kalamazoo River Superfund Site, a biota investigation was carried out in 1993 to assess the concentrations of PCBs and other regulated constituents in resident common carp and white suckers in the Former Bryant Mill Pond section of Portage Creek. These samples were collected prior to the Removal Action, and as such, represent pre-IRM conditions

MHLLC collected channel catfish and white suckers from Portage Creek in 1998-1999 to monitor fish PCB concentrations during the USEPA Removal Action at the Former Bryant Mill Pond. These samples, analytical results for which are included in Appendix E, similarly represent pre-IRM conditions.

The MDEQ LTM Program, previously discussed, collected yearling and adult carp, yearling and adult white suckers, and one brown trout. The results have been published in three reports prepared by the MDEQ (CDM, 2001a, 2002b, and 2002c). Additional fish were collected under the LTM Program in 2006 and included fish from Portage Creek. These data are not yet available and the results have yet to be published.

Screening Criteria

The MDCH manages a Fish Contaminant Monitoring Program that includes the collection of a variety of fish from lakes and streams throughout the State of Michigan. The Fish Contaminant Monitoring Program evaluates fish samples for PCBs and many other potential contaminants to determine appropriate fish consumption advisories. The Trigger Levels for total PCBs in fish are as follows:

1. General Population: 2.0 parts per million (ppm)
2. Women of Child-Bearing Age and Children Under 15 Years:
    - One meal per week: 0.05 ppm
    - One meal per month: 0.2 ppm
    - Six meals per year: 1.0 ppm
    - No consumption: 1.9 ppm

The MDEQ considers these values to be potentially applicable criteria for fish at the Allied OU. Determination of the applicability of cleanup criteria for biota and other environmental media at the Allied OU will be made by the USEPA, in consultation with the MDEQ, during review of ARARs in the FS.

4.6.1 Site Biota Investigation

MHLLC collected fish samples at the Allied OU in 1993 and 1999 to determine the concentrations of regulated chemicals in species of fish that may be consumed either by humans or piscivorous (fish-eating) ecological receptors. The sampling area is shown on Figure 11. Table 2-10 presents a summary of the biota samples submitted for chemical analysis for the RI.

Eleven whole-body white sucker, 11 carp fillet, and 6 carp remaining-carcass samples were collected and analyzed in November 1993 for percent lipids, TCL pesticides, total mercury, and PCBs by Aroclor. One of the carp fillet samples collected in 1993 was also analyzed for PCDFs/PCDDs. The analytical results for these samples are discussed in Sections 3.2.2 and 4.2 of *Technical Memorandum 11* (BBL, 2000a), and are presented in Table 4-7A(CD), Table 4-7B(CD), Table 4-7C(CD), and Table 4-7D.

The 1998-1999 Removal Action significantly changed the conditions in the area of Portage Creek where fish samples were collected. The analytical results for fish samples collected in 1993 are representative of Pre-IRM conditions. In November 1999, 11 samples of resident white suckers were collected in the Former Bryant Mill Pond and submitted for analysis of lipids and PCBs. These samples were collected shortly after the Removal Action was completed, and are expected to be more comparable to current site conditions than earlier (1993) data. Table 4-7A(CD) presents a summary of the analytical results for those samples.

Data from the LTM Program within the Former Bryant Mill Pond reach includes, adult carp skin-off fillet samples, adult white sucker whole-body samples, yearling white sucker whole-body samples, and yearling carp whole body samples. For more detailed information on the results of the LTM Program, see the LTM reports published by the MDEQ from sampling years 1999, 2000, and 2001 (CDM, 2001a, 2002b, and 2002c).

For the fish samples collected between 1993 and 2002, the frequency of detection and range of detected concentrations of PCBs in carp samples are summarized in Table 4-6A, while exceedances are summarized in Table 4-6B. A simple comparison of upstream (Monarch Mill Pond, 11 carp collected in 2001) and site (Former Bryant Mill Pond, 11 carp collected in 2001) can be made of the post Removal Action data (CDM 2002a). For the skin-off filet, resident adult carp, the wet weight mean total PCB concentration was 0.17 mg/kg for Monarch Mill Pond and 0.72 mg/kg for the Former Bryant Mill Pond, over a factor of four increase between the upstream and site fish. The lipid normalized PCB concentration was 9.0 mg-PCB/kg L-N for Monarch Mill Pond and 23 mg-PCB/kg L-N for the Former Bryant Mill Pond, over a factor of two increase and very similar to the increase in surface water PCB concentration discussed previously. The frequency of detection and range of detected concentrations of PCBs in white sucker samples are summarized in Table 4-6C, and screening criteria exceedances are summarized in Table 4-6D. The frequency of detection and range of detected concentrations of chemicals detected in carp and white sucker samples for percent lipids, TCL pesticides, total mercury, and dioxins/furans are summarized in Table 4-6E and Table 4-6F, respectively (white suckers were not analyzed for dioxins/furans).

5. Fate and Transport of PCBs

PCBs are the primary chemical of concern at the Allied OU, and an understanding of the fate and transport of PCBs at the OU, under current conditions, provides a basis for risk management decisions. In this section, the properties and processes governing the transport and the potential fate of PCBs at the Allied OU under current conditions are described. The primary factors influencing PCB fate and transport at the OU are the characteristics (physical and chemical) of PCBs and the media in which they are present. A review of the characteristics of PCBs provides a basis for discussion of the transport and fate of PCBs from residuals, soils and sediments at the OU through transport mechanisms in air, surface erosion, groundwater, surface water, and fish. These are the media of concern from the standpoint of environmental impacts and potential human health risks. The site-specific information presented in Section 4 is combined with the characteristics of PCBs to provide a comprehensive description of the potential fate and transport of PCBs under current conditions at the OU. This description provides a basis for analysis of additional remedial actions that may be considered in the forthcoming FS.

It should be recognized that there are other contaminants (mainly TAL inorganics) present at the site that must be monitored along with an ongoing PCB monitoring program at the site. The fate and transport of these other constituents are not discussed in this section because it is likely that the fate and transport mechanisms are similar to those of PCBs given the volume of material in question and the short transport distance to surface water associated with this OU.

Although PCBs are generally considered to be have limited mobility in water-saturated soil environments, the considerable mass of residuals present at the Allied OU increases the likelihood that PCBs will partition into a dissolved phase or sorb to mobile colloids that may move with groundwater. Due to the high clay content and low hydraulic conductivity of the residuals, water is typically expected to migrate slowly through the saturated residuals where it eventually mixes with the groundwater. Other chemicals that are dissolved in groundwater, including several dominant ions, typically are more mobile than PCBs given greater transport distances. This difference becomes less relevant with shorter transport distances. Short transport distances through groundwater to surface water are a dominant characteristic at this OU.

5.1 Physical and Chemical Factors Affecting PCB Fate and Transport

PCBs are a class of synthetic organic compounds that includes 209 individual compounds referred to as congeners. The various congeners differ in the number and arrangement of chlorine atoms on the biphenyl molecule, but they all have the same basic chemical structure and similar physical properties. In the United States, PCBs were produced for commercial purposes exclusively as mixtures of PCB congeners by Monsanto Industrial Chemicals Company under the trade name Aroclor. The average chlorine content of a particular Aroclor product is, in most cases, evident in the specific product name. For example, Aroclor 1242 is 42% chlorine by weight, while Aroclor 1254 is 54% chlorine by weight. Although most PCBs produced in the United States were used in manufacturing electrical transformers and capacitors, some Aroclors were also used in other applications, including hydraulic fluids, cutting oils, heat transfer fluids, and quench oils. From 1957 through 1971, PCBs in the form of Aroclor 1242 were used in the manufacture of carbonless copy paper. However, the signature of Aroclors subject to weathering in the natural environment can make laboratory quantification of Aroclors uncertain. This weathering results in a laboratory analytical quantification of an Aroclor that may not be the original manufactured Aroclor mixture.

In general, PCBs are chemically and thermally stable (Amend and Lederman, 1992), fairly inert, and have low solubility in water. In general, the lower the water solubility of a chemical the more likely it is to be adsorbed onto solids. The presence of other dissolved compounds in water may affect the solubility of PCBs (Suthersan, 1997). For example, if certain organic compounds are dissolved in water at sufficient concentrations, the energy necessary to dissolve PCBs may be reduced. This condition is referred to as *cosolvency*. The solubility of PCBs in water may be increased in the presence of codissolved non-polar chemicals, such as hydrocarbons.

PCBs have very high octanol-water partitioning coefficient (K_{ow}) values. The octanol-water partitioning coefficient represents the propensity for a chemical to partition between a polar phase (water) and a non-polar phase (octanol) – similar to partitioning in the soil matrix between soil organic matter and groundwater (Suthersan, 1997). The K_{ow} value is determined as the ratio of the solubility of PCBs in octanol (an organic matter surrogate) to the solubility of PCBs in water. Thus, a higher K_{ow} value indicates a greater tendency for a chemical to sorb to organic materials (e.g., peat, humic acids, and other organic colloids) in soil.

The degree of adsorption of PCBs in soils is a function of the soil organic content and the adsorption properties of the specific PCB compounds that are present. Adsorption properties are generally characterized by an organic carbon partitioning coefficient denoted by K_{oc}. The K_{oc} values for PCBs are relatively high (Chou and Griffin, 1986), which means that PCBs readily adsorb to organic material in media such as sediments and soils.

Taken together, the combination of low water solubility and high K_{ow} and K_{oc} values indicates that PCBs have a strong affinity for soils and suspended solids, especially those high in TOC (Chou and Griffin, 1986). PCBs bind to the organic matter fraction decreasing the dissolved fraction and encouraging the transport of PCBs sorbed to solids (i.e. particulate transport).

Other than organic content, soil or sediment characteristics that affect the mobility of PCBs include soil density, particle size distribution, moisture content, and permeability. Meteorological and physical conditions such as amount of precipitation and the presence of organic colloids (micron-sized particles) can also affect the mobility of PCBs in the environment (USEPA, 1990). PCBs that are dissolved or sorbed to mobile particulates (e.g., colloids) may also migrate with groundwater in sediments and soils (discussed further in Section 5.3).

PCBs can be transported by air, either adsorbed onto airborne dust particles or in a vapor phase that results from volatilization. The chemical characteristics that control the adsorption of PCBs to dust particles are described above. The Henry's Law constant of a compound provides an indication of its tendency to volatilize, and thus provides a means for ranking the relative volatility of chemicals. Henry's Law constants are used to calculate the rate of volatilization from water and can be obtained from literature or calculated by dividing the vapor pressure value of a chemical by its water solubility. PCBs have low Henry's Law constant values relative to other organic compounds (Agency for Toxic Substances and Disease Registry [ATSDR], 2000), which means that at equilibrium, the fraction found in water will be higher than the fraction found in air.

PCBs tend to be persistent in sediments and soils, and there is no known abiotic process that significantly degrades PCBs in these media (ATSDR, 2000). Biodegradation of PCBs in soils under aerobic or anaerobic conditions is slow, especially in soils with high organic carbon content. At PCB concentrations below about 50 ppm, the rate of dechlorination is often very slow or non-quantifiable (ATSDR, 2000). This is likely because PCBs are so tightly bound to the soil that at relatively low concentrations they are not bioavailable to the biodegrading organisms (ATSDR, 2000).

5.2 PCB Transport in Air

Volatile emissions from exposed residuals or surface soils containing PCBs can result in a local low-level and measurable increase in ambient airborne PCB concentrations (BBL, 1994a). The results of air sampling conducted along the perimeter of the Allied OU in 1993 indicate that the mean PCB concentrations in site air samples were generally an order of magnitude below the SRSL of 0.02 $\mu g/m^3$ identified under Michigan air quality regulations.

The USEPA conducted personal and perimeter air monitoring during the Removal Action activities to assess worker exposure to dust potentially containing PCBs, evaluate the impact of site activities on ambient air quality, and verify the adequacy of protection to nearby commercial and residential areas. The sampling programs included:

- Background air sampling for PCBs prior to site activities to provide information regarding the appropriate level of controls during site operations, and for the selection of appropriate personal protective equipment.

- Personal air monitoring during excavation, waste drying, and stabilization activities to evaluate the levels of exposure to PCBs. The personal air sampling action level for PCBs was set at 0.25$\mu g/m^3$.

- Perimeter sampling for PCBs during excavation, waste drying, and stabilization activities to evaluate the impact of these activities on ambient air quality and demonstrate the protection of adjacent residences and businesses. The perimeter air sampling alert level was set at 0.18 $\mu g/m^3$ and the action level set at 0.5$\mu g/m^3$.

PCBs were not detected above the action or alert levels during excavation or drying activities. One perimeter air sample collected during stabilization activities contained PCBs above the alert level, but below the action level. No personal air samples contained PCBs above the action level. Based on these results, the USEPA concluded that no significant PCB migration was occurring during excavation, waste drying, or stabilization activities. When the Removal Action was completed (in October 1999), the Former Bryant Mill Pond was backfilled with clean fill and the residuals and PCB-containing soils and sediments in the Bryant HRDL and FRDLs were covered with a protective layer of clean fill.

The IRM actions conducted since the Removal Action was completed have involved much smaller scale excavation and grading operations and no waste drying or stabilization activities. Therefore, these IRM actions did not require extensive air monitoring. Prior to the start of response activities when the Air Investigation was conducted, there were PCBs in the surface materials over much of the 89-acre site. The Removal Action resulted in excavation and backfilling of 29 acres of land in the Former Bryant Mill Pond where PCBs were exposed at the surface, and the IRM has involved capping of another 22 acres of land in the Bryant HRDL and FRDLs where PCBs were exposed at the surface. Although PCBs may still be exposed at the surface at some locations within the Former Operational Areas (Type III Landfill, Western Disposal Area, and Monarch HRDL), the Removal Action and IRM activities have greatly reduced the area with exposed PCBs since the air sampling was conducted in 1993. In so doing, these actions have reduced the potential for PCB emissions to air by substantially decreasing the acreage of land with surface materials that contain PCBs.

5.3 PCB Transport in Groundwater

A number of factors may affect the migration of PCBs in groundwater, including:

- The chemical characteristics and concentrations of the specific PCB congeners/Aroclors present at the site (as described in 5.1);

- The characteristics of the PCB source medium (e.g., PCB-containing soils and residuals), including physical state, mass, location, geotechnical characteristics (e.g., bulk density, grain size and distribution, porosity, permeability, moisture content, organic content), heterogeneity, manner and characteristics of containment (if any), concentration and distribution of any cosolvents, and susceptibility to biological interaction or disturbance;

- The characteristics of the other (non-PCB containing) soils above the water table, including topography, vegetation, soil composition and heterogeneity, geotechnical characteristics, and depth to groundwater;

- The hydrogeological and hydrogeochemical conditions near the source medium, including temperature, pH, conductivity, dissolved solids, DO, alkalinity, and ORP; groundwater velocity, presence and composition of mobile colloidal particles; and presence and concentration of cosolvents; and

- The local meteorological conditions, including daily and seasonal temperature ranges and fluctuations, annual precipitation, barometric pressure, and relative humidity.

Water that is in contact with residuals is prone to chemical alteration whereby chemical constituents of the residuals are dissolved in the water. PCBs in a dissolved phase move freely with the groundwater and, if not constrained, may be transported further. Dissolved PCBs are subject to a number of different retardation processes, including sorption and various chemical reactions. As a result of retardation, PCBs that are dissolved in groundwater generally move more slowly through the aquifer than the groundwater itself. The physicochemical properties of PCBs favor adherence to soils (especially organic soils) in a solid phase. For PCBs sorbed to a solid phase to be mobile, they must be attached to particles that are small enough to travel through the interstices of the residuals and/or soil matrix. PCBs sorbed to colloid-sized particles (or smaller) can be held in suspension and could also be transported through the interstices of the residuals and/or soil matrix.

5.3.1 Comparison of Groundwater, Seep, and Leachate Analytical Results

The chemistry of groundwater is influenced by interactions with soils, rocks, and other subsurface materials. The general chemical characteristics of individual groundwater samples are often summarized by plotting the relative concentrations of selected subsets of the major anions and cations. Two of the more commonly used plotting procedures are Piper diagrams (which depict the relationships among the major anions and cations in a trilinear form) and Stiff diagrams (which depict the same relationships as polygons).

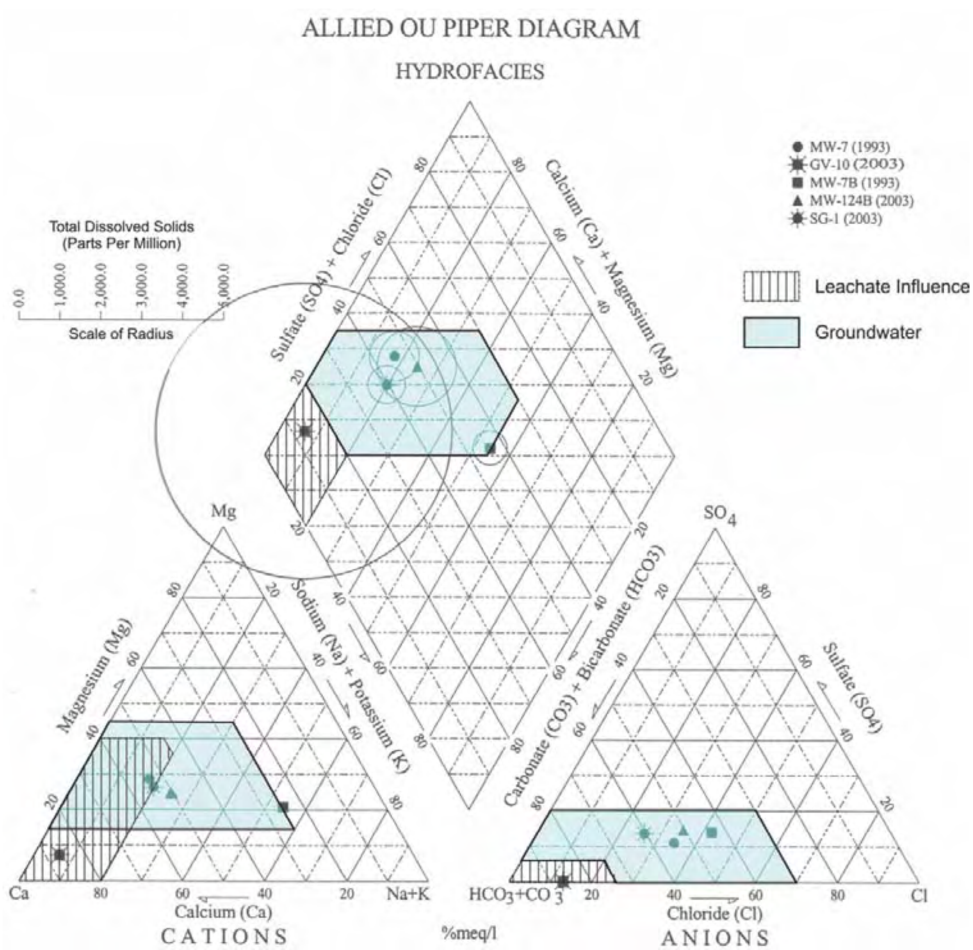
Piper and Stiff diagrams along with other indicator parameters have proven useful in identifying the chemical signature of leachate and in assessing the influence of leachate on groundwater quality at the Allied OU. Piper and Stiff diagrams for groundwater, seep, and leachate samples collected in 1993, 2002, and 2003 are assembled in Appendix Q. Diagrams for one surface-water sample collected in 2003 are also provided to illustrate the hydrochemistry of the surface water into which site groundwaters discharge. The indicator parameter data for the groundwater, seep, and leachate samples collected in 1993, 2002, and 2003 are summarized in Tables 5-1A, 5-1B, and 5-1C, respectively.

Review of the Stiff and Piper diagrams presented in Appendix Q indicates a very distinct chemical signature for the leachate sample collected at gas vent GV-10. By comparing this signature to the plots for other wells, it is apparent that groundwater at much of the site has been impacted by leachate. As stated earlier, given the mass of residual material at the site and the close proximity of the wells to the waste material, it is expected that a leachate signature would be identified in the groundwater at the site. The Stiff and Piper diagrams confirm that this is the case. Once in the groundwater, the leachate will then be transported the relatively short distance to the regional groundwater discharge feature, Portage Creek.

A general discussion regarding the hydrogeochemistry of groundwater and leachate samples used to prepare the Stiff and Piper diagrams at the Allied OU are discussed below.

5.3.1.1 Piper Diagrams

A Piper diagram is a trilinear plot that shows the proportions of dominant cations and anions in one or more water samples (Fetter, 1988). The cation and anion data are plotted as percentages of the total ionic charge with all concentrations expressed in milliequivalents per liter (meq/L). The proportions of cations in a water sample are represented on an equilateral triangle in the lower left field, and the proportions of anions are represented in a second equilateral triangle on the lower right field. Proportions of cation pairs and anion pairs are plotted on a central rectilinear field, which also identifies the concentration of TDS as the radius of a circle shown around each sample plot. The TDS concentration is calculated from the concentrations of ions in solution. An example Piper diagram is shown below.

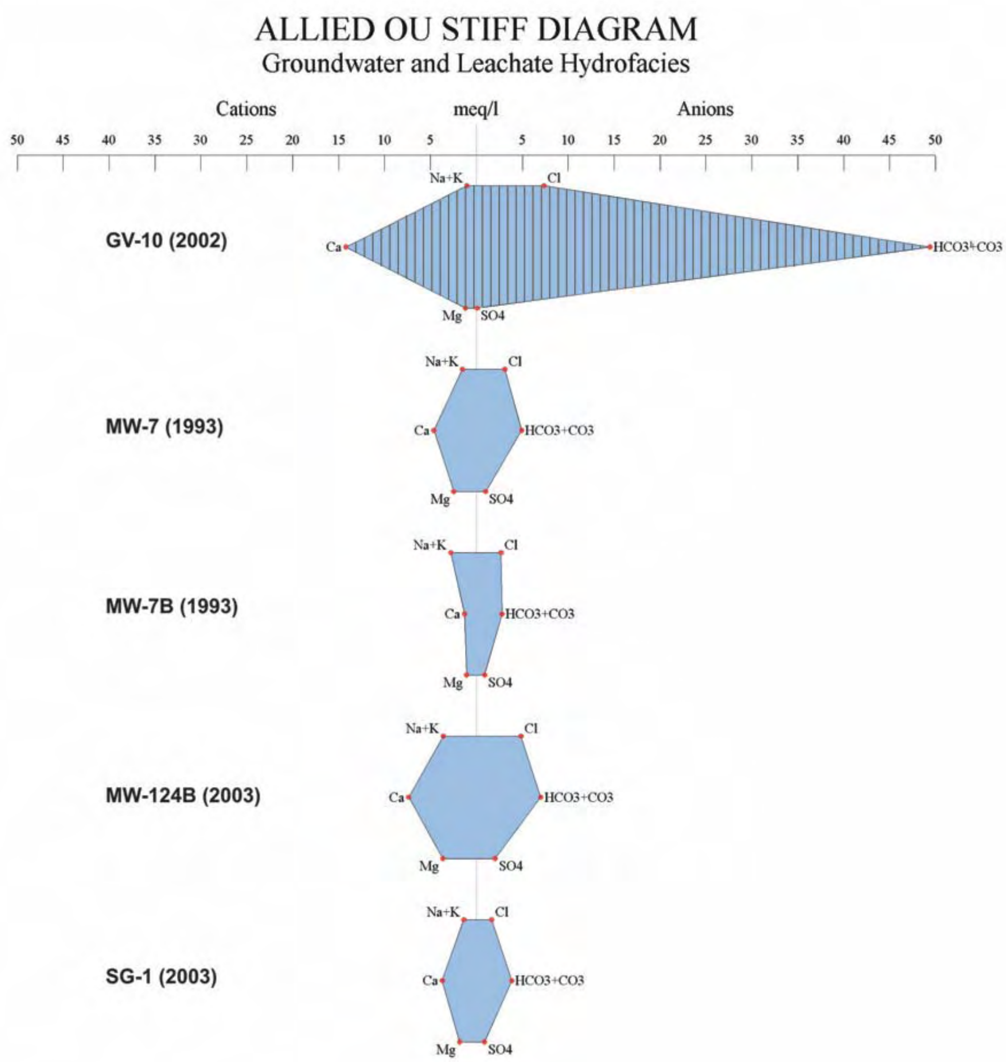


This method of representing water chemistry allows subtle changes, relationships, or trends in an array of samples to be observed. A particular application of the Piper plot is to determine the degree to which water samples may be related and whether a water sample is a mixture of other waters. Groundwater samples that plot together and share a similar hydrogeochemical signature can be assumed to be hydrogeochemically related. For example, groundwater samples that plot similarly to that of GV-10 may be influenced by leachate. Groundwater samples that plot away from GV-10 (e.g., MW-7) may be less influenced by leachate. The number of wells used to characterize leachate is minimal and therefore this RI uses the data from GV-10 as a surrogate to represent leachate characteristics site wide.

5.3.1.2 Stiff Diagrams

Stiff diagrams are used to plot the major ion pairs for water samples as a polygonal shape on several axes measured in meq/L (Fetter, 1988). Cations are plotted on the left side and anions plotted on the right to create a characteristic pattern for each water sample. The size and shape of each Stiff diagram varies with the concentrations of the dominant ions, making hydrochemical similarities or dissimilarities between samples readily identifiable. Stiff diagrams for groundwater, seep, and leachate samples collected in 1993, 2002, and 2003 are included in Appendix Q. The Stiff diagram for the 2003 surface water sample is also included. Example Stiff diagrams are shown below.

The Stiff diagram for the GV-10 (2002) leachate sample is immediately distinguishable by the very long, pointed peak for CO_3^{2-} + HCO_3^- extending sharply to the right, the virtual absence of SO_4^{2-}, and the relative symmetry of the cation values (Na^+ + K^+) and Mg^{2+}. This characteristic shape is found to varying degrees in several of the groundwater and seep samples collected in 1993, 2002, and 2003. Again, the number of wells used to characterize leachate is minimal and therefore this RI uses the data from GV-10 as a surrogate to represent leachate characteristics site wide.



5.3.2 Effects of the IRM on Hydrologic Regime

The IRM have modified the hydraulic conditions of groundwater at the Bryant HRDL and FRDLs area of the Allied OU. The sealed-joint sheetpile acts to impede the lateral flow of water toward Portage Creek. Where it is driven into the upper aquitard, the sheetpile limits the potential for water to flow beneath it and enhances the performance of the permanent sump system in removing potentially-impacted water before it enters the shallow groundwater system near the creek. A leachate collection pipe was installed beneath the perimeter drainage ditch at the Bryant HRDL and FRDLs, directing water into the recovery system at PS-1 (see Appendix F). The landfill cap constructed over the Bryant HRDL and FRDLs prevents infiltration of water into the waste, reduces the production of leachate, and limits recharge to the groundwater table in this area. Runoff from the Bryant HRDL and FRDLs is now discharged from the settling basin into Portage Creek. The collective effect of the

IRM components on groundwater quality is expected to occur over time, and several years may be required before the full benefit of the completed IRM is reflected in the groundwater quality.

Other than the southeast perimeter of the Western Disposal Area near Portage Creek, where the sheetpile was installed and the groundwater sump system operates, the hydrology at the remainder of the site (including the Type III Landfill, the Monarch HRDL, Panelyte Property and Marsh, Stryker Corporation Property, and adjacent properties) has not been directly affected by the IRM.

5.3.3 PCBs Transport in Groundwater, Leachate, and Groundwater Seeps

The most recent groundwater, seep, and leachate data (i.e. post IRM) are considered to be the most representative of actual *in situ* conditions at the Allied OU, not only because of the improved methods to obtain representative samples, but because conditions in certain areas of the site have been modified considerably since the RI began. The USEPA Removal Action in the Former Bryant Mill Pond resulted in excavation of the very material into which many of the monitoring wells that were sampled in 1993 had been installed. The IRM activities included the removal of residuals from the East Bank Area, as well as from areas between the sheetpile and the west bank of Portage Creek. All of the residuals and soils removed from these areas were consolidated in the Bryant HRDL and FRDLs, graded, and covered with a landfill cap. A recovery system removes groundwater from within the sealed-joint sheetpile wall; both the wall and the recovery system alter the flow of subsurface water along the perimeter of the Bryant HRDL and FRDLs. These actions have changed groundwater conditions in these study areas such that the analytical results for samples collected previously are representative of pre-IRM conditions.

Figure 36B presents the distribution of PCBs in samples collected from groundwater monitor wells, leachate wells, and temporary seep wells following the IRM. The data associated with the locations at which PCBs have been detected in recent samples indicate that PCBs are migrating with groundwater toward Portage Creek in some portions of the Allied OU. Information relevant to interpreting the data from each location with a recent detection is summarized in the following paragraphs.

Post IRM sampling and analysis have confirmed detectable concentrations of PCBs at interior wells MW-8A, MW-120A and MW-120B. In addition, post IRM sampling and analysis have confirmed detectable concentrations of PCBs at perimeter wells FW-101(MW-206P), MW-200A, SP-611, SP-508, SP-242, MW-209, MW-122AR, and MW-221R. As stated earlier, given the mass of residual material at the site and the close proximity of the wells to the waste material, it is expected that detectable concentrations of PCBs would be identified in the groundwater at the site. The PCB analytical results confirm that this is the case. Once in the groundwater, PCBs are expected to be transported the relatively short distance to the regional groundwater discharge feature, Portage Creek.

Additionally, PCBs were detected in samples of groundwater collected from seeps SP-G, SP-H, and SP-J located in the northwestern area of the Former Type III Landfill, which contains various types of non-process industrial wastes and residuals. The contaminated groundwater is discharged from the seeps and flows directly into Portage Creek or the adjacent wetlands. This process is expected to result in near surface erosion typical of springs that serve to develop a more efficient transport path for particulates. The particulates transported by the seeps will include those associated with the PCB contaminant.

5.4 PCB Transport from Surface Water Runoff and Soil Erosion

PCB transport from surface water runoff and soil erosion may occur from the Former Operational Areas. The Former Operational Areas that have not been capped, including Monarch HRDL, Western Disposal and Type III Landfill are known to contain PCBs. It is assumed that these Former Operational Areas will be addressed as part of the remedy; therefore this pathway has not been fully evaluated.

This transport mechanism has been partially assessed in three areas of the site. 1) Surface soil samples were collected at four locations subject to erosion east of the Monarch HRDL. 2) Sediment samples were collected from nine locations in the Panelyte Marsh adjacent to the Western Disposal Area. 3) Three surface sediment samples were collected from areas downgradient of the seeps G, H and J. A total of 15 samples were analyzed. The results from the samples collected in these three areas of the site had detectable concentrations of PCBs which supports the hypothesis that PCBs are being transported through the surface water runoff and soil erosion mechanism.

5.5 PCB Transport in Portage Creek

PCBs may enter Portage Creek from groundwater, surface water runoff and erosion, air deposition, instream sediments, bank erosion and upstream sources. Once in Portage Creek, PCBs bioaccumulate in biota, and will be discussed in the next subsection. Several factors that govern the transport and fate of PCBs in a moving surface water body, such as a river or creek, include:

- The chemical characteristics and concentrations of the specific PCB congeners/Aroclors present at the site;
- The physical and chemical conditions of the PCB source media (e.g., sediments, soils, groundwater, upstream surface water);
- General surface water quality characteristics (e.g., DOC, TSS, pH, temperature);
- General sediment quality characteristics (e.g., fraction organic carbon, chemical composition, particle size distribution);
- The hydrological conditions and environmental setting (e.g., channel geometry, geometry of drainage basin, underlying geology, flow rates and gradient, groundwater recharge, biological systems); and
- Climate and meteorological conditions.

The distribution and dynamics of PCBs in river systems are the subject of study in *A Risk Management Strategy for PCB-Contaminated Sediments* (National Research Council, 2001). As detailed in this comprehensive resource, PCBs in river systems are generally found in three phases: dissolved in the water column, associated with DOC, and sorbed to particles. PCBs that are freely dissolved or associated with DOC may move within the sediment pore space, enter the water column, or volatilize. PCBs that are attached to particles are subject to hydrodynamic forces such as settling, resuspension by turbulence, deposition, and burial. Due to the generally low solubility and high affinity of PCBs for adsorption to natural solids (especially the organic fraction of those solids), the transport and fate of PCBs in river systems is intimately associated with the transport and fate of solids.

The most significant historical source of PCBs to Portage Creek from the Allied OU was the discharge of PCB contaminated paper wastes to Portage Creek at the Bryant Mill Pond. The excavation of PCB-containing sediments, residuals, and soils and subsequent replacement with clean fill in the Former Bryant Mill Pond has isolated these materials from direct contact with surface water, and permanently removed the largest source of

PCBs to Portage Creek at the Allied OU. Today, the sources of PCBs to Portage Creek from OU1 include the erosion of contaminated soils and sediments, as well as the discharge of contaminated groundwater.

Surface Water Analysis

As discussed in Section 4, the MDEQ has been conducting an LTM Program. Surface water samples were collected during dry and wet weather conditions. For the purposes of this discussion, sampling stations immediately upstream of the site (Cork Street) and downstream of the site (Alcott and Bryant Street) were reviewed relative to PCB fate and transport attributable to OU1.

Data collected prior to the completion of the USEPA Removal Action, completed in October 1999, are not representative of current conditions and therefore not discussed in this section. In addition, surface water data collected by the MHLLC during 1993 and 1994 investigations had a significantly higher method detection limit, approximately 0.05 μg/L, versus the current method detection limits, approximately 0.001 μg/L.

Surface water PCB concentrations can be correlated to flow rates, temperature, and TSS levels (CDM 2003c). In addition to the overall correlation with temperature, the PCB detection frequency more than doubles (from 43% to 91%) when water temperatures are greater than 15º C. This dramatic difference may be attributable to low flows in the summer months when groundwater recharge contributes more significantly to surface water flow, and when temperature may favor desorption of PCBs to the surface water (via biotic and abiotic processes). Temporal trends in PCB concentrations cannot be reliably extracted from the post removal surface water data set. It can be stated that PCB concentrations in surface water, at the OU, have decreased significantly since the Removal Action, however, because average PCB concentrations increase from upstream (0.015 μg/L at Cork Street) to downstream locations (0.031 μg/L at Alcott/Bryant Street) by a factor of two, the OU appears to be contributing PCBs to Portage Creek.

5.6 PCBs in Fish

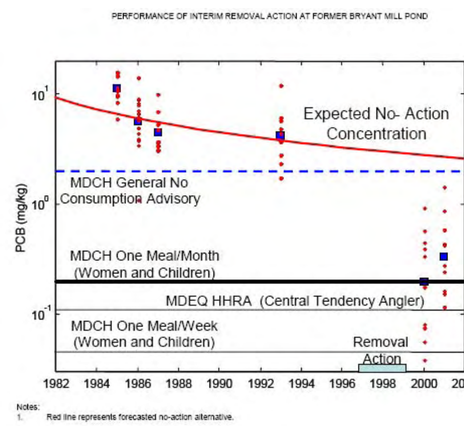
PCB concentrations in Kalamazoo River fish were determined by the MDEQ to pose a potential risk to ecological receptors that consume fish (CDM, 2003a). Consumption of fish also was determined to be a significant potential pathway for human exposure to PCBs at the Kalamazoo River Superfund Site (CDM, 2003b). The MDCH has issued fish consumption advisories for the segment of Portage Creek in which the Allied OU is located since 1977 due to PCB contamination. The Removal Action conducted in 1998-1999 and

IRM activities from 2000 to date resulted in removal of the vast majority of residuals and PCB-containing sediments that were in direct contact with Portage Creek surface water. As expected, the Removal Action resulted in substantial declines in PCB concentrations in fish.

The most recent analytical data for Portage Creek fish samples were obtained by the MDCH for the Fish Contaminant Monitoring Program and by the MDEQ Environmental Response Division LTM Program from 1999 to 2002. Because the Removal Action substantially changed the chemical, physical and habitat of Portage Creek at OU1, a comparison of fish tissue concentrations before and after the Removal Action was made. However the available data are not sufficient to analyze temporal trends post-Removal Action. Additional fish were collected under the LTM Program in 2006 and included fish from Portage Creek. These data are not yet available and the results have yet to be published.

PCB concentration in fillet and whole-body samples varied with fish-length and lipid content. Temporal forecasts and spatial comparisons that ignore these factors will lead to erroneous conclusions (Kern, 2003).

Carp were sampled both before and after the removal action, and post removal concentrations are substantially lower than would have been expected under natural attenuation (see right). Under a no action alternative, concentrations at Bryant Mill Pond are predicted to have been around 1.0 mg/kg in 2020. In 2000 and 2001, after the removal action, Carp fillet concentrations averaged 0.3 mg/kg and 0.4 mg/kg respectively. This suggests that the removal action may have accelerated recovery by over 20 years relative to natural attenuation.



As discussed previously, temporal trends in PCB concentration cannot be reliably extracted from the post-Removal Action fish-tissue data presently available. However, a simple comparison of upstream (Monarch Mill Pond, 11 carp collected in 2001) and site (Former Bryant Mill Pond, 11 carp collected in 2001) can be made (CDM 2002a). For the skin-off filet, resident adult carp, the wet weight mean total PCB concentration was 0.17 mg/kg for Monarch Mill Pond and 0.72 mg/kg for the Former Bryant Mill Pond, over a factor of 4 increase between the upstream and site fish. The lipid normalized PCB concentration was 9.0 mg-PCB/kg L-N for Monarch Mill Pond and 23 mg-PCB/kg L-N for the Former Bryant Mill Pond, over a factor of two increase and very similar to the increase in surface water PCB concentration discussed previously.

6. Conclusions

Over the past decade, an extensive RI at the Allied OU of the Kalamazoo River Superfund Site was conducted. The Allied OU has, by far, the strongest dataset from which to make remedial decisions than any other operable unit at the Kalamazoo River Superfund Site. To meet the primary goals of the RI, which was conducted in accordance with an AOC (between the State of Michigan and the MHLLC) and associated work plans consistent with the NCP, NREPA, and CERCLA, a wide variety of investigations were performed to characterize the physical and chemical aspects of the site. These investigations have resulted in an understanding of the nature and extent of regulated constituents in site media and the processes governing their transport and fate.

Remediation activities at the OU actually began during the RI. The Removal Action in the Bryant Mill Pond and the IRM, which focused on the Bryant HRDL and FRDLs, resulted in consolidation and isolation of a large mass of PCB impacted waste and sediments. The removal of a large mass of PCB material from the stream bed and floodplains of Portage Creek during the Removal Action resulted in a profound reduction in surface water and fish tissue PCB concentrations. The later IRM work to cap waste materials in the Former Bryant HRDL and FRDLs has eliminated the infiltration of rainwater through the contaminated waste in this area, which has certainly slowed the production of leachate. It is also understood that the sheetpile and groundwater extraction system have resulted in a reduction of contaminant transport to Portage Creek. These activities have caused substantial changes such that some of the data collected from these study areas in the early phases of the RI no longer describe current conditions. Although some earlier-collected data have been excluded, a considerable body of information is available that is sufficient to complete the FS; assess the present state of the OU; and inform decisions on future remedial actions.

The FS should consider the current and future land-uses at this OU and determine whether an area poses an actual or potential risk to human health and the environment. Areas that will be restricted to industrial uses should be evaluated with respect to the State's health-based soil criteria for industrial/commercial land use. Areas zoned residential need to be evaluated with respect to the State's health-based soil criteria for residential land use. Areas of the site should also be considered for their ecological value where criteria developed in the BERA would apply, and the sediments at the site should be evaluated with respect to the criteria developed for the HHRA. It is assumed that where soil vs. sediment criteria will be applied is dependent on an inundation period, yet to be determined, consistent with how the Record of Decision was executed for the Willow Blvd/A-site Operable Unit. Groundwater and surface water at the site should also be considered in relation to the states relevant criteria.

Source containment measures are still needed at the site to control PCB exposure pathways at the Allied OU. The exposure pathways still existing include:

Soils/Sediment

The COCs at the Allied OU, which include PCBs, SVOCs, and TAL constituents, are present in the surface and subsurface soils, sediment, and residuals in all areas of the site. In particular, PCB impacts exist in all areas of the site and have been delineated using both chemical confirmation sampling and visual observations of residual material from boring locations. An understanding of the nature of the waste material (residuals), derived from the relatively large number of samples collected in the source areas at the site (i.e. the Former Operational Areas), has justified the use of visual observations to delineate the extent of impacts at the site. The data within the RI provides a basis for assuming that other COCs are similarly distributed with the PCB impact associated with the site.

The data indicates that contaminant concentrations exceed the soil screening criteria (background and unrestricted residential) and other potentially applicable soil criteria (commercial/industrial and ecological) in the Former Operational Areas. Contaminated residuals have also migrated onto the Residential/Commercial Areas adjacent to the Former Operational Areas and the Former Bryant Mill Pond at concentrations that are assumed to exceed the soil screening criteria (background and unrestricted residential) and may exceed other potentially applicable soil criteria (commercial/industrial and ecological) as well. Due to the effectiveness of the Removal Action in the Former Bryant Mill Pond, contaminant concentrations in soil are not expected to exceed the soil screening criteria in this area of the site.

The data indicates that contaminant concentrations exceed the sediment screening criteria (mainly the PCB Method Detection Limit) at the site. Within the Former Bryant Mill Pond the vast majority of sediment sample locations have concentrations below the sediment screening criteria. Sediment samples within the Former Bryant Mill Pond with contaminant concentrations that exceed the sediment screening criteria are located mostly in the vicinity of Seep G, H, I, and J, or in the upstream portion of the Former Bryant Mill Pond near the sheetpile. Other sediment samples with contaminant concentrations that exceed the sediment screening criteria are located along Portage creek near the Former Operational Areas (specifically in the vicinity of sheetpile SP-416 to SP-611), and in the Panelyte Marsh.

Groundwater

As stated earlier in the RI, given the mass of residual material at the site and the fact that the waste material sits in groundwater, it has been shown that PCBs are identified at detectable levels in the groundwater at the site. Once in the groundwater, PCBs and other associated contaminants are being transported the relatively short distance to the regional groundwater discharge feature, Portage Creek.

The current groundwater extraction system is not currently operated to achieve the required goal of keeping groundwater levels to within one foot of the historic groundwater level. However, the extraction system appears to be capturing some contaminants in groundwater. The operation of the current groundwater extraction system, in conjunction with the sealed joint sheetpile, does not eliminate all groundwater flow paths that may transport contaminants to Portage Creek in the areas where this system has been installed (the Bryant HRDL and FRDLs). Additionally, hydraulic control measures such as sheetpile and a groundwater extraction system do not exist in other areas of the site where waste remains (Monarch HRDL, Former Type III Landfill, and portions of the Western Disposal area). While great care was taken when installing the existing sheetpile at select areas of the site, it is not an impermeable structure. Therefore, impacted groundwater is presumed to still be migrating into Portage Creek along stretches of the OU where large volumes of waste materials exist.

During the most recent sampling, PCBs were detected in several of the GSI monitoring wells located along Portage Creek near the Former Operational Areas, with most of the PCB detections below the GSI screening criteria. The data also indicate that non-PCB contaminant concentrations exceed the screening criteria (mostly GSI and generic drinking water criteria) in all areas of the site where groundwater has been collected.

The presence of springs on the banks of Portage Creek is characteristic of a groundwater-fed drainage system. Throughout the RI, a reliance on the word “seep” can be seen. In all cases, where “seeps” are discussed in either the text or tables, it must be understood that “seeps” mean “springs”. The flow nets, head level in the aquifers, and contour maps of the various groundwater units that conduct groundwater all indicate that Portage Creek is a strong groundwater discharge zone. The presence of significant spring activity is consistent with the hydrogeological conditions and flow and transport of groundwater on this site. This phenomenon represents an important groundwater pathway by which site contaminants are still being transported to Portage Creek.

During the most recent sampling, PCBs were detected in several of the groundwater seep monitoring wells located along Portage Creek near the Former Operational Areas, with PCB detections above the GSI screening criteria in two locations. The data also indicate that non-PCB contaminant concentrations exceed the screening criteria (mostly GSI and generic drinking water criteria) in almost all areas of the site where groundwater seep samples have been collected.

Surface Water

Although temporal trends in PCB concentration cannot be reliably extracted from the 2000-2006 surface water data, average PCB concentrations increase from upstream (0.015 μg/L at Cork Street) to downstream locations (0.031 μg/L at Alcott/Bryant Street) by a factor of two. Thus, the site still appears to be contributing PCBs to Portage Creek surface water. Contaminant concentrations at both the upstream and downstream sample location exceed the surface water screening criteria (Michigan Human Health/Wildlife Water Quality Criteria).

Fish Tissue

As discussed previously, temporal trends in PCB concentration cannot be reliably extracted from the post-Removal Action fish-tissue data presently available. However, a simple comparison of upstream (Monarch Mill Pond, 11 carp collected in 2001) and site (Former Bryant Mill Pond, 11 carp collected in 2001) can be made (CDM 2002a). For the skin-off filet, resident adult carp, the wet weight mean total PCB concentration was 0.17 mg/kg for Monarch Mill Pond and 0.72 mg/kg for the Former Bryant Mill Pond. Mean contaminant concentrations for both the upstream and downstream fish samples exceed the Michigan Department of Community Health criteria of One Meal/Week for Women & Children and are below general population no consumption criteria.

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